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Annual Technical Report No. 1

INTERRELATIONSHIP OF IN SITU ROCK PROPERTIES, EXCAVATION METHOD, AND MUCK CHARACTERISTICS

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Report Period

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Ву

H. F. Haller H. C. Pattison B. Shimizu



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The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Advanced Research Projects Agency or the U.S. Government.

FOREWORD

This report presents the technical findings and accomplishments of research into the interrelationship of in-situ rock properties and the characteristics of muck produced by virious excavation methods. The period covered is from January 12, 1971 through January 11, 1972.

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INTRODUCTION AND SUMMARY

PURPOSE

The purpose of the program is to develop a method for predicting the materials handling properties of muck from the engineering properties of rock, and a means of selecting the most suitable transportation equipment for muck produced by various excavation systems, through the concept of Muck Designation Numbers (MDN's).

CONCLUSIONS

Program activities have been confined to data collection, processing, development of tentative MDN's, and preliminary correlation with rock properties and muck handling systems. Although final conclusions cannot be stated, it is apparent that the size distribution of the sampled muck from high strength rocks differs distinctly from that of muck from most of the low strength rocks. Exceptions may be associated with the excavation method and/or the rock structure. Refinement of MDN's and detailed correlation analysis is within the scope of the 1972 program.

REFERENCE TO DETAILS

Details of the topics summarized below are arranged under the same headings in the report.

SUMMARY

1. Technical Problems

The importance of increasing the speed of underground excavation while decreasing the cost is emphasized by recent surveys which indicate that a great volume of this work will be required in the near future. Considerable research has been conducted to determine relationships between rock properties and rock drillability, excavation, and support requirements. However, data concerning the characteristics of muck produced by various excavation methods in various rocks are not available for general use in selection or design of muck transport systems. Correlations have not been established between muck characteristics, the properties of the in-situ rock and the components of rapid excavation systems. In the absence of these data, an adequate basis does not exist for optimum selection from the transportation systems in current use, or for development of the high speed systems required in the future.

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2. General Methodology

The r search plan is to collect muck samples, lithologic and operating data, and rock specimens where necessary, from operating tunnels; determine muck characteristics and roc! properties by physical testing; correlate and analyze rock and muck properties, and quantify relationships through Muck Designation Numbers (MDN's); and to correlate rock and muck characteristics, MDN's, and the components of rapid excavation systems with muck transport system capabilities.

Lithologic data consists of descriptions of rocks, their classifications by probable origin and subsequent alteration, and Rock Quality Designations (RQD's) which indicate the frequency of discontinuities. Operating data includes descriptions of the equipment and methods used in the total excavation system. Rock test data includes unconfined uniaxial compressive strength, dry unit weight, and hardness where available. Commercial muck test data includes size distribution and shape, moisture content, and dry loose unit weight.

3. Technical Results

3.1 Site Selection

A list of current and scheduled tunnels was compiled to assure that program objectives could be met. Sites for data and sample collection were selected with emphasis on mechanical operations in hard rock. Some soft rock and conventional tunnels were included as examples of unusual advance rates and systems. The current list is enclosed as Appendix A.

3.2 Sample and Data Collection

Operating data and thirty four muck samples were collected from fifteen sites. Resampling was done at four sites to confirm the reliability of initial results. All other samples reflect differing lithologies, operating methods, or equipment.

Rock specimens for engineering property tests were collected from twenty formations at twelve sites.

Shield operations in two formations, conventional tunneling in eleven formations, tunnel boring machine (TBM) operations in fifteen formations, and raise boring machine (RBM) vertical reaming in two formations were sampled during the year.

Rock types sampled include four classified as very High Strength, ten as High Strength, ten in the Medium - Medium to High range, three Low, and six Very Low Strength. A basis for these classifications follows in the body of the report.

? 3 Physical Testing

Test procedures were reviewed in detail. Standard tests, approved by the American Society for Testing and Materials, were selected for use by commercial laboratories to insure consistency of results.

Contracts to perform muck tests were negotiated with thirteen commercial laboratories. Samples were delivered for testing and shipment of fractions to the U. S. Bureau of Mines, Pittsburgh Mining and Safety Research Center (PMSRC), for additional tests. At the end of the contract year, muck tests by commercial laboratories had been reported on thirty three sets of samples, and on twenty three sets by the PMSRC.

Contracts to perform rock tests were negotiated with five commercial laboratories. Nineteen sets of specimens were delivered for testing, of which two were destroyed in preparation, and the remainder were tested and reported.

Other tests reviewed and recommended for inclusion in the second year of the program will provide data on Schmidt hardness, abrasiveness, and stress-strain relationships.

3.4 Data Processing

A format was developed for printout of lithologic, muck, and rock test data; test results have been stored on punch cards, and printouts of these data are included as Appendix B. A form was developed for narrative and graphic presentation of lithologic, operating, rock and muck test data. These "System Data Sheets" are included as Appendix C.

Summaries of rock and muck properties which affect materials handling, and of muck handling system parameters were prepared as guidelines in the development of correlation analysis programs.

3.5 Development of MDN's

The aze distribution curves from initial sampling varied distinctly, generally as had been expected, and development of an algorithm to correlate MDN's, in-situ rock properties, and excavation methods was initiated.

Continued sampling produced some curves which fit well with the initial curves, and others which suggested establishing additional categories. Curves of similar form were plotted together, and preliminary MDN's were assigned. The resulting composite curves are shown as Figures 1 through 8.

MDN assignments are tentative, and will undoubtedly be changed to reflect solutions in problem areas, which may involve use of raw data derivatives, additional rock property data, varying the predictor equation, or separate MDN series for special types of boring machines.

3.6 Transport System Selection

A listing of equipment capabilities, system constraints, and MDN applications was prepared for the unitized and semi-continuous systems in common use. The listing also is tentative, and will be refined and quantified in the 1972 program.

4. DoD Implications

The data accumulated under the program are non-existant elsewhere in rapid excavation technology and should provide a more rational basis for selection of materials handling systems for excavation methods in current use. These data will also be invaluable to the design of the equipment required to match the improved advance rates resulting from current excavation research.

5. Implications for Further Research

Collection is recommended of data and samples from stratified volcanic and fine grained igneous rocks, and from excavation methods not previously sampled in the metamorphic rocks, to provide information on formations and methods which were not encountered in the first year.

Field work at new sites in formations similar to those previously sampled is also recommended, either to provide data on different methods, or to determine what similarities and differences in muck characteristics may exist.

Continuation of the sampling program in conventional and shield operations is suggested to provide operating data on transport systems in high advance rate tunnels.

Resampling at selected sites to improve the confidence level of collected data is considered advisable.

Collection of hardness, abrasiveness, and stress-strain data previously recommended has been included in the program plan for 1972.

Sampling muck produced by unusual rock breaking methods under current development, such as the electron beam and the water cannon, is recommended to provide data for design of compatible transport systems.

6. Special Comments

No equipment has been purchased or developed, nor has any invention been made in the course of the work performed under this contract.

1. TECHNICAL PROBLEMS

The effectiveness of planning for new tunnels has been limited by the quantity and quality of information concerning subsurface conditions which has been available. For many reasons, owners and owner-agencies often have been reluctant to collect data on the properties of materials to be excavated. or to publish information which has been collected. Interested contractors have been forced to base proposals on their own assessments of conditions to be encountered, and to base cost estimates on methods and equipment which may not be well suited for conditions as they exist. Generally, significant allowances are made, both for contingencies which can be anticipated and for those which cannot be foreseen.

The importance of a more logical approach to selection of methods and equipment for tunneling has been emphasized by recent estimates of the great volume of this work probable in the near future, and by the wider application of tunnel boring machines which require rock property data as a basis for design. A trend towards collection and dissemination of more adequate exploratory information for tunnel sites *; apparent in the reports of subsurface investigations published by some owner agencies.

Progress has been made and is continuing in research to determine relationships between rock properties, drillability, excavation, and support requirements. Recent investigations have shown, however, that very little information has been collected on the characteristics of the muck produced by the various excavation methods, and that correlations between the engineering properties of rock, muck characteristics, and the components of excavation systems have not been established.

In the absence of muck characteristic data, an adequate basis for selection of optimum transportation methods and equipment does not exist, and tunneling progress and cost have been affected adversely. Muck data are also a basic requirement for engineering the improvements to existing transport systems, and the development of the new systems which will be necessary to keep pace with the higher rates of excavation predicted for the future.

2. GENERAL METHODOLOGY

The objectives of the program are to develop a method for predicting materials handling properties of muck from the in-situ properties of rock, and a means of selecting the most suitable transportation equipment for muck produced by various excavation systems. The major emphasis is on mechanical excavation of hard rock. However, some soft rock and some conventional operations are included as examples of unusual advance rates, equipment, and operating memods.

The program plan is to collect muck samples and operating data from tunnels in rock of known properties; collect specimens from sites where the in-situ properties are unknown; determine muck characteristics and rock properties by physical testing; correlate and analyze rock and muck properties and quantify relationships through the concept of Muck Designation Numbers (MDN's); and to establish correlations between rock and muck characteristics, MDN's, the components of rapid excavation systems, and selection of muck transport equipment.

3. TECHNICAL RESULTS

3.1 SITE SELECTION

A list of operating and scholuled tunnels was prepared originally to assure that program objectives could be met. This list has been revised to incorporate changes, and is included as Appendix A. All but one of the tunnels listed are expected to be in operation during the coming year. Letter inquiries inviting program participation by off-continent tunnel operators have met with no response. These tunnels have been deleted from the list.

An original reluctance of tunnel contractors to approve site access has been overcome at all but one site. Operators, although under no obligation to participate in the program, have become cooperative when convinced that sampling and data collection are scheduled on a noninterference basis, with full observance of tunnel safety requirements.

Access to operating mine tunnels usually requires more operator participation than access to a contract tunnel. The impact of economic conditions has reduced emphasis on and interest in research. While mine operators were most cooperative in the 1971 program, less data is expected from such sources in 1972.

Early planning assumed that one basis for site selection would be the availability of rock property data at specific sites. Experience has shown that collection of these data is necessary from the majority of locations, and the program has been modified to reflect this requirement.

3.2 SAMPLE AND DATA COLLECTION

Muck samples and operating data have been collected from fifteen tunnel sites. Of thirty four samples, six were collected from sites visited only once. Resampling was done in similar formations at four sites to confirm the reliability of initial results. All other samples reflect differing lithologies, operating methods, or equipment.

The scope of collecting in-situ rock data has been greater than was anticipated, because of the nondisclosure policies of some owners and agencies and because formations encountered in some locations could not be correlated with the existing rock data. Rock specimens were collected for engineering property tests from twenty formations at twelve sites, under a modification of the contract.

Shield operations in two lithologic formations, conventional tunneling in eleven formations, TBM operations in fifteen formations, and RBM raise boring in two formations have been sampled to date. Rock types represented include four classified as Very High Strength, ten classified as High Strength, two in the Medium to High Strength range, eight in the Medium range, three Low, and six Very Low Strength. One rock sampled remains to be classified.

Seven of the sampled sites are no longer available for field work. One tunnel has been closed indefinitely following a disastrous explosion and fire, and excavation of interest to the program has been completed at the others.

3.3 PHYSICAL TESTING

Test methods were studied in detail to ensure that tests performed by commercial laboratories would yield consistent results. The following American Society for Testing and Materials (ASTM) standard methods were selected as specifications:

C566-67: Total Moisture Content by Drying

C136-67: Sieve or Screen Analysis of Fine and Coarse Aggregates

C117-69: Materials Finer than No. 200 Sieve in Mineral Aggregates by Washing

C29-69: Unit Weight of Aggregate, Loose Weight Determination

C170-50: Compressive Strength of Natural Building Stone

Specifications for the last test procedure have been modified to provide for greater accuracy in specimen preparation so that results will be comparable to those reported by other rock property research programs.

Contracts to perform muck tests have been negotiated with thirteen commercial testing laboratories. Collected samples were delivered for testing and shipment of minus two inch fractions to the U. S. Bureau of Mines, Pittsburgh Mining and Safety Research Center (PMSRC) for additional tests to be performed at this facility. At the end of the contract year, muck tests by commercial laboratories had been reported on thirty three sets of samples, and on twenty three by the PMRSC. One sample, tested commercially, was lost in transit to the PMRSC, and the remainder of these reports are expected during 1972, the samples having been collected too late for processing during the contract year.

Contracts to perform tests on rock specimens were negotiated with five commercial laboratories. Nineteen sets of specimens were delivered for testing of which two sets were destroyed in preparation. Reports on seventeen sets of specimens were received, and one set collected is being held for possible future testing.

Standard methods of testing abrasiveness were reviewed to determine the feasibility of collecting these data from tests on muck samples. The standard ASTM tests were found to measure the resistance of the sample to abrasion, rather than the abrasive effect on other materials. The latter is the property of greater interest in materials handling. Fractions of all muck samples are being retained for possible tests for this property, pending selection of an appropriate test procedure.

Results of hardness tests by the Shore scleroscope, a laboratory instrument which tests hardness by rebound of a hammer, are available for only three of the rock formations sampled. Additional tests by this method were found to be beyond the scope of this study. Hardness testing by the Schmidt hammer, a portable device which also tests rebound hardness, is described as nondestructive and relatively inexpensive. Rock specimens are also being retained for future tests by this method which are currently scheduled for 1972. Schmidt hardness values shown have been inferred as described in the footnote to the illustrations.

Modification of the standard test procedure was found necessary in testing muck from some low strength rocks. Screen testing the samples in the natural state was performed prior to the standard tests to avoid distortion of the curves caused by the disintegration of material during the wash screening which normally preceds dry seive analysis. Natural screen test results are identified and shown as dotted lines on the size distribution curves.

3.4 DATA PROCESSING

A summary of rock and muck properties which affect materials handling, the range of the values of muck and rock properties which will be available, and the parameters of muck handling systems was prepared as a guideline in the development of correlation and analysis programs.

A format was developed for computer printout of lithologic, rock and muck data. Test results received to date have been stored on punch cards. Printouts of these raw data are included as Appendix B. Blank spaces on the printout indicate that data is not available on the date of the report.

Narrative and graphic summaries were prepared to combine these data with descriptions of the excavation systems from which rock and muck samples were taken, and are included as Appendix C. Rock strength classifications are based on uniaxial compressive strength, and conform with those proposed by D. U. Deere, et al, in the "Engineering Classification and Index Properties for Intact Rock", referenced above. These classifications are:

Very High Strength - Greater than 32,000 psi
High Strength - 16,000 - 32,000 psi
Medium Strength - 8,000 - 16,000 psi
Low Strength - 4,000 - 8,000 psi
Very Low Strength - Less than 4,000 psi

Grain eize classifications of igneous rocks, from A. Johannsen's "A Descriptive Petrology of Igneous Rocks", 1931, are used as follows:

Very Coarse - above 3 cm
Coarse - 1 to 3 cm
Medium - 1 to 10 mm
Fine - below 1 mm

From J. F. Kemp's "A Handbook of Rocks", 1950, sedimentary rocks of fragmental grains above 2 mm, are classified as conglomerates, while those below 2 mm in size are classified as sandstones or siltstones.

Symbols used to describe the shape of particles in the sample fractions between screen sizes are the following

A - Angular S - Sub-Angular
P - Platy R - Rounded
E - Elongated C - Cubic
I - Irregular Sp - Spheroid

The curves show the percentage of the total sample weight passing one screen size and retained on the next. Screen sizes below 1/2" were selected to provide openings which become progressively smaller by approximately fifty percent, as shown below:

<u>Screen Size</u> #4 #8 #16 #30 #50 #100 #200 Nominal Square Openings, Inches 0.187 0.094 0.047 0.023 0.012 0.006 0.003

The abbreviation NA is used to indicate that an item of data is not available.

3.5 DEVELOPMENT OF MDN'S

In accordance with the program plan, which provides for placing major emphasis on data collection during the first year, analysis of data and development of MDN's has been preliminary. As data first became available, test results were reviewed to confirm the validity of the conceptual classification criteria. Based on a plan of classification by materials handling characteristics, the proposed designation system employed seven numbered categories in which to group excavation products by size and size distribution. Numbers were assigned in a progression from No. 1 for muck with a relatively large maximum piece size and a predominant distribution in the 1" to 200 mesh range to No. 7, in which the maximum size is relatively small and the predominant distribution is in the minus 50 mesh sizes. The concept also recognized that muck characteristics would vary with the excavation method, and contemplated modifying the MDN's to distinguish between excavation techniques.

Initial field work was scheduled at sites where rock strengths varied over a wide range, and which would provide examples of shield, machine, and conventional operations. The size distribution curves of the muck from these sites, (Identification Numbers H-1, 5-1, CL-1, NAST-1, and SF-1, Appendix C), varied distinctly, in general accordance with the criteria, except that the size range of the predominant distribution was somewhat higher than had been inferred.

Using the initial data as a guide, a preliminary algorithm was developed for data analysis to correlate MDN's, in-situ rock properties, and excavation methods. The quantitative relationship sought was a predictor equation, obtained by multiple regression of the physical property data obtained from the rock sample tests and a predictor equation for the MDN. A discussion of this technique follows.

In simple regression, it is supposed that with each observation value, there is another quantity which can be observed or somehow related to the observation. After n observations, there exists a series of pairs, (x_1, y_1) , (x_2, y_2) , \cdots , (x_n, y_n) . The question we wish to answer is to determine if there is a relationship between y and x and how this relationship can be obtained.

One may assume that there is such a relationship, and that this relationship is linear. With this assumption, one may write

$$y = \alpha x + \beta \tag{1}$$

The x_i , $i=1, \cdot \cdot \cdot$, n, are the values of the independent variable x, and the y_i , $i=1, \cdot \cdot \cdot$, n, are the values of the dependent variable y. α and β are the coefficients which will have to be determined from the observation points.

It is possible that a relationship exists between x and y, but the relationship is not linear. A possible alternate in this case is to find another variable, x^l , related to x, such that y can then be linearly related to x^l . The new variable x^l will then be used in place of x in the discussions that follow.

Assuming that the linear relationship is valid, we can create an error term which is the sum of the squares of all deviations of observed values from the linear Equation (1). Thus the error ϵ is

$$\epsilon = \sum_{i=1}^{n} (y_i - (\alpha x_i + \beta))^2$$
 (2)

and determine α and β so ϵ is minimum. This simple regression is known as the method of "least squares". The solution can be shown to be:

$$\alpha = v_{xy}/s_x^2 \tag{3}$$

$$\beta = \overline{y} - \alpha \overline{x} \tag{4}$$

where

$$s_{\mathbf{x}}^{2} = \frac{1}{n-1} \sum_{i=1}^{n} (x_{i} - \overline{x})^{2}$$
 (5)

$$v_{xy} = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \overline{x}) (y_i - \overline{y})$$
 (6)

 \overline{x} and \overline{y} are the arithmetic averages of the x_i and y_i respectively.

Equations (3) and (4) give the necessary coefficients in terms of observed values for the predictor Equation (1). If y had been the MDN, and x an in-situ rock property (or some transformation of it), then this simple regression would have resulted in a predictor equation for the MDN.

A procedure similar to the simple regression technique will be applicable if we want to relate a dependent variable y to several independent variables $x_1, x_2, x_3, \dots, x_{m-1}$. (Note the x_1, x_2, \dots, x_{m-1} are independent variable and not the observation points themselves). If n observations are taken, then one has the following sets of points: $(y_1, x_1, 1, x_2, 1, x_3, 1, \dots, x_{m-1}, 1), (y_2, x_1, 2, x_2, 2, x_3, 2, \dots, x_{m-1}, 2), \dots, (y_n, x_{1n}, x_{2n}, x_{3n}, \dots, x_{m-1}, n)$

A linear relationship is assumed to exist between y and x_1 , x_2 , x_{m-1} , n. Thus, one has

$$y = \alpha_0 + \alpha_1 x_1 + x_2 y_2 + \cdots + \alpha_{m-1} x_{m-1}$$
 (7)

The coefficients α_0 , α_1 , \cdots , α_{m-1} will have to be determined from the n observations of the variables.

To solve for the coefficients requires the manipulation of certain arrays. Defining the following one dimensional arrays:

$$\alpha = \begin{pmatrix} \alpha_0 \\ \alpha_1 \\ \vdots \\ m-1 \end{pmatrix} \quad ; \quad \mathbf{w} = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} \tag{8}$$

Let A be the two-dimensional array.

$$A = \begin{pmatrix} 1 & x_{1,2} & x_{2,1} & \cdots & x_{m-1,1} \\ 1 & x_{1,2} & x_{2,2} & \cdots & x_{m-1,2} \\ \vdots & & & & & \\ 1 & x_{1,n} & x_{2,n} & \cdots & x_{m-1,n} \end{pmatrix}$$
(9)

Setting up an error term is no longer as easy. One possibility is

$$z_i = y_i - \alpha_0 - \sum_{j=1}^{m-1} \alpha_j x_{j,i}$$
; $i = 1, 2, \cdots, n$ (10)

Two other one dimensional arrays are needed:

$$z = \begin{pmatrix} z_1 \\ z_2 \\ \vdots \\ z_n \end{pmatrix} \quad ; \quad z^T = (z_1, z_2, \cdots, z_n) \tag{11}$$

z and z^T are both functions of the observation points and the coefficients, which are still unknown. One can set up a covariance matrix z

$$V = zz^{T} = \begin{pmatrix} z_{1}^{2} & z_{1}z_{2} & \cdots & z_{1}z_{n} \\ z_{2}z_{1} & z_{2}^{2} & \cdots & z_{2}z_{n} \\ \vdots & & & & \vdots \\ z_{n}z_{1} & z_{n}z_{2} & \cdots & z_{n}^{2} \end{pmatrix}$$
(12)

The coefficients α_0 , α_1 , \cdots , α_{m-1} which minimize the error term can be shown to be obtained from

$$\alpha = J^{-1}A^{1}V^{-1}w \tag{13}$$

where

$$\mathbf{J} = \mathbf{A}^{\mathbf{T}} \mathbf{V}^{-1} \mathbf{A} \tag{14}$$

However, V is a function of z which contains the unknown coefficients themselves. By assuming that the random errors in Equation (10) have zero mean and a constant variance α^2 regardless of z. V can be shown to be equal to α^2 I, where I is the unit maxim. If this is so, then the coefficients for the predictor equation will be given by

$$\alpha = (A^{T}A) A^{T} w$$
 (15)

A^T is the transpose of the matrix A given by Equation (9).

The general computational procedure is as follows:

- (1) Form the array A as given by Equation (9).
- (2) Obtain the transpose, A^T, from A. This is just a matter of interchanging rows and columns.

- (3) Compute A^TA, then (A^TA)⁻¹, then (A^TA)⁻¹A^T. This involves a series of matrix multiplications and matrix inversion. These techniques are readily available from a computer.
- (4) Form the array w from Equation (8).
- (5) Multiply the result of Step (3) by the result of Step (4). This yields a set of coefficients α_0 α_1 , α_1 .
- (6) Test for goodness of fit or the quality of the predictor equation.

A basic assumption is that the predictor equation is linear, and that the independent variables to use are the observation variables themselves. It may be necessary to define another set of variables x_1^{-1} , x_2^{-1} , \cdots , x_{m-1}^{-1} to use in order to obtain a linear relationship.

It often happens that the independent variables are themselves related. If a linear relationship exists between any two of the independent variables. $(A^TA)^{-1}$ will be singular, i.e., A^TA will have zero determinant, and hence $(A^TA)^{-1}$ cannot be computed. If this is so, α is difficult to compute, and the standard errors of the calculated coefficients are huge, giving an inaccurate predictor equation. This problem can be circumvented by performing the regression analysis with one variable, then with two variables, etc. while being careful when this problem arises. One may combine linearly any two variables that are highly correlated and use the combined variable as in the dependent variable.

To obtain Equation (15) from Equation (13), it was necessary to assume that the off-diagonal terms in Equation (12) are zero. If this is not so, the observations are known to be auto-correlated, and will result in an inefficient predictor equation. The marked presence of auto-correlation implies that alternate modes of estimation should be used.

Good computer routines exist which are available on most computers, including routines for matrix transpose, matrix multiplication and matrix inversion, together with standard routines to compute means and standard deviations of a set of observations.

In multiple regression to predict an MDN, the MDN is treated as the dependent variable. The set of independent variables may include the following:

- (a) Dry Unit Weight, DUW
- (b) Compressive strength, Fc
- (c) Rock quality designation, RQD
- (d) Hardness, H
- (e) Abrasiveness, Ab

Some of these variables may be excluded from the analysis; others still undefined may be included. The regression analysis may be performed using one or more of these variables.

A set of observations is obtained, and with each set of observations, an MDN is indicated. A table with the following entries will be created:

MDN	DUW	Fc	RQD	<u>H</u>	Ab

It is seen that y corresponds to MDN, and DUW, Fc, RQD, H, and Ab, correspond to x_1 , x_2 , x_3 , x_4 , and x_5 , respectively. The matrix in Equation (9) corresponds to the observation points. The array in Equation (8) corresponds to the MDN indicated in column 1. The predictor equation may be obtained from Equation (15).

Several iterations of this analysis should be performed on the computer in order to determine which variable or combinations of variables are appropriate to include in the predictor equation. Certain tests can be performed to determine the quality and accuracy of this predictor equation. With computer routines readily available, several iterations may be performed with reasonable cost and in a very short time.

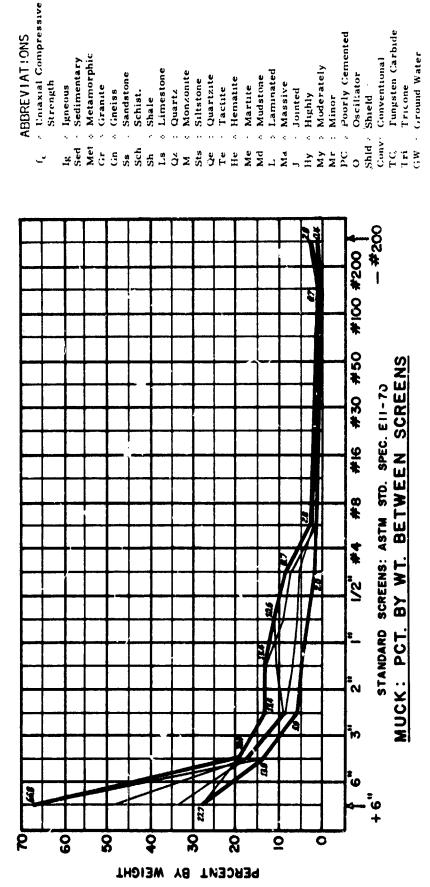
During algorithm development, re-sampling at three of the original sites confirmed the distinctive shape of the size distribution curves, but was impossible at the other two sites because one tunnel had progressed

into a different formation, and the TBM had been removed from the other. Sampling at other sites produced some curves which fit well into the original categories, and others which were distinctive enough to suggest establishing additional categories. When most of the data had been collected, curves of similar form were plotted together, and tentative designation numbers were assigned. The resultant composites are shown as Figures 1 through 8 on the following pages. The prefix "C" was added to MDN's for muck produced by conventional operations, and "M" and "S" were used to indicate boring machine and shield systems. To avoid reducing data derivatives to extremely small values, rocks with compressive strengths of lKPSI or less have been assigned arbitrary strengths of 1. In the few cases where Shore hardness was available, values have been converted to the Schmidt scale; other schmidt hardness values have been inferred from data published by D. U. Deere, et al, in the "Engineering Classification and Index Properties for Intact Rock," referenced above. The "T" prefix was added to all MDN's to indicate the preliminary nature of the assignments.

The tentative nature of the MDN assignments must be stressed, since changes will undoubtely result from analysis—and from resolution in problem areas which became apparent in the course of the program. These include the apparent lack of direct correlation between middle range MDN's and some rock properties, the characteristics of the muck from tunnel boring machines using drag cutters, and the performance of the raise boring machine which was sampled late in the program. A solution to the first problem may be found in the use of raw data derivatives, and of additional rock property data such as Schmidt hardness, stress-strain curves, Young's modulus, and Poisson's ratio, which will be collected during the second year of the program. Varying the predictor equation or setting up separate MDN series for drag cutter TBM's and for RBM's may be necessary to solve the others. Because the effectiveness of the proposed solutions rend to be confirmed, use of computer techniques has been confined to data storage and retrieval and to development of the algorithm described above.

3.6 TRANSPORT SYSTEM SELECTION

The following listing of equipment capabilities, system constraints, and MDN applications is taken in part from Report No. FRA-RT-71-57 "Materials Handling for Tunnels", HN 8080, Holmes & Narver, Inc. and Resource Management Corp., Sept. 1970, prepared for the U. S. Department of Transportation, Washington, D. C., with additional details provided by the authors. The list, consistent with the goals of the program in the first year, is preliminary, and will be refined and quantified in scheduled future work.



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	ı				ľ											_
		ROCK		,		ROCK		HARDNESS			M	MACHINE CUTTERS	CUTTER	S		
LASS		TYPE	OCLASS TYPE STRUCT. K LBS		KQD %		SHORE	PCF SHORE SCHMIDT G, W. METHOD	G, W.	METHOD	DISC	ROL'R DRAG CONE	DRAG	CONE	MAA. SIZE OBSERVED	
Į,		02 M	Ig Qz M Mr J	25	83	162		55	Dry	Conv					‡' x 3' x 2'	
a I	_	02 M	Ig Q2 M Nr J 38		83	105		55	Dry	Conv					3-1/2' x 2' x 2'	
Met		Qe-Te	Met Qe-Te LMy J 26		80	178		90	Dry	Conv					2-1/2° × 1° × 1/2°	
Met		Met Te	My J 15 (Est) 70	15 (Est)	2.0	181		14	Dry Conv	Conv					27" x 18" x 12"	

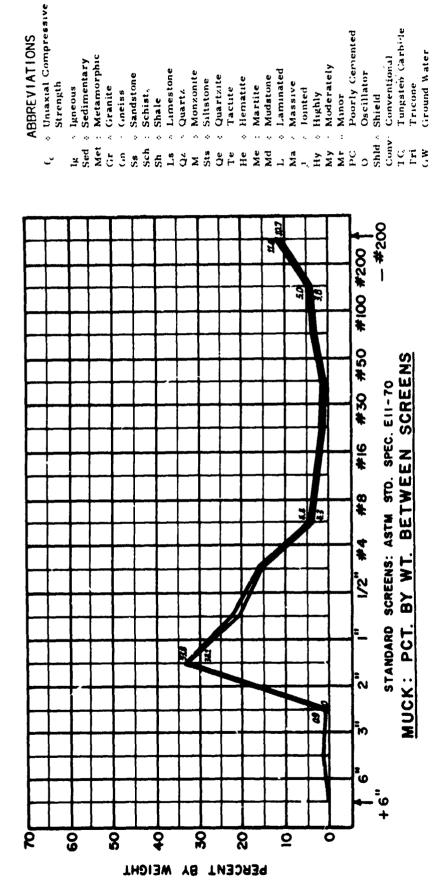
ROCK, OPERATING DATA, & MUCK SIZE RANGE, MDN T-CI, C2 FIGURE 3-1 Inferred from D. U. Deere AD 64t 610-1966

3 Uniaxial Compressive lk : ligneous
Sed : Sedimentary
Met : Metamorphic
Gr : Granite
Gn : Gneiss
Ss = Sandstone
Sch : Schist.
Sh : Sha'e
Lis : Linnestene
Qu : Quart.
M : Mondonite
Sis : Siltstone
Qu : Quart.
He : Hematite
Me : Martite
Md : Martite
Md : Martite
Md : Martite
Md : Martite
Md : Martite
My : Minor
PC : Laminated
My : Moderately
Mr : Minor
PC : Poorly Cemented
O : Oscillator Conv. Conventional
TC > Fungsten Carbide
Tri : Tricone
GW - Ground Waver **ABBREVIATIONS** Strength Sh!4 & Shield Conv. Conven - #200 #100 #200 #16 #30 #50 BY WT. BETWEEN SCREENS STANDARD SCREENS: ASTM STD. SPEC. E11-70 #8 2 22 MUCK: PCT. 60 8 \$ દ્ભ 8 0 O PERCENT BY WEIGHT

		ROCK			- 40	ROCK	HAR	HARDNESS		- CA CA 1.	M	MACHINE CUTTERS	сстте	ts.	11 / 10 / A 4 14
10E/	CLASS	TYPE	CLASS TYPE STRUCT	K LBS 7 PCF	7		SHORE	SHORE SCHMIDT C W. METHOD	○ W.	METHOD	DISC	DISC ROL'R DRAG CONE,	DRAG	CONE	OBSERVED
GA.1	I.g.	C.r	Mr J	35	20	191		55	Dry	Conv					2-1/2, x 2, x 1.
11.3	Sed	StsSh	MMrL 22	22	0°	152	8.7	£\$	איה	Conv					18" x 19" x 4"
H	JI	(,,	Mr J	32	80	162		52	Mr	Conv					3, < 5, × 1,
\AS13	I a	Gr	Mr J	13	00	751		42	M	Conv					?-162' x 1-1 2' x 1'
H.2	ıε	GrGn	Mr J	39	80	104		5 <i>د</i>	Mr	Conv					2' x 1-1'?' x 1'
11.4	767 7	Sed StsSh	MMFI. 22	22	06	16.6	48	£ ‡	Drv	LBM			43 I.C		×" × *" × +"

ROCK, OPERATING DATA A MUCE SIZE RANGE, MIN I-C3, MI Interred in the Deere AD 646 10-1966.

FIGURE 3-2

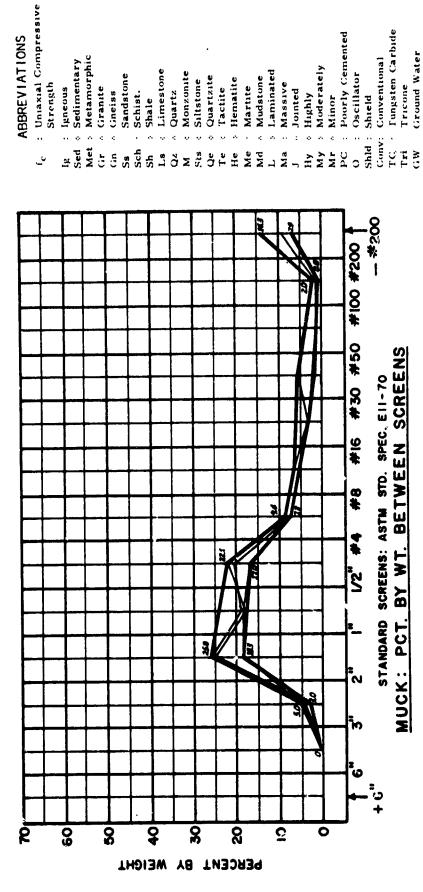


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		ROC K				ROCK	HAR	HARDNESS			NE	MACHINE CUTTERS	CUTTER	Ş	1
	CLASS	INPE	SFRUCT.	ic in ROD DU	X	DCW PCF	SYORE	THAT CLASS IN PERIOD ALBS π PCF SHORE SCHMIDT G. W. METHOD	G. W.	EXCA! METHOD	DISC	DISC POL'R DRAG CONE	DRAG	CONE	MAA. SIZE OBSERVED
£-1	sed 's	s,	Ma	=	Ş	171	6.1	o†	Dry	TBN	TBN: 47 (Center triple - 1)	r triple -	11		"+' * * " * "2/1-2
?:	Sed	ĵ	Sed ~5 Ma 16 92 171	10	9.2	171	ol	5 †	Dry	Dry TBM 47 (Center triple = 1)	47 (Center	r triple =	1)		3" x 9" x 1"
dr err	ed ron	ا ایر د	In creed ron 1 Deere AD: 40 010-1900	40 010-1	ge, e.										

ROCK, OPERATING DATA, & MUCK SIZE FANGE, MDN T-M2 FIGURE 3-3



		ROCK				ROCK	HAR	HARDNESS			NIA	MACHINE CUTTERS	CUTTE	RS	
DENT	CLASS	TYPE	NO CLASS TYPE STRUCT. K LBS	Ac in ROD DUW	RQD DUW		SHORE	SHORE SCHMIDT G. W. METHOD	G. W.	EXCA (DISC ROL R PRAG COVE	ROL R	PRAG	COVE	MAN SIZE OBSERVED
LAWR	LAW: Sed Ls	Ls	Ma	x 0	100	17c	46	42	Drv	TBM 11TC		16TC		TCTF1	TCTr1 3" x 2-1/2" x 1/2"
LA W 2	LAW2 Sed Ls	L.s	Ma	æ	100 176	176	÷	42	Dry	Dry TBM 11TC	11TC	16 T C		ICTra	ICTr1 3" x 2" x 1/2"
LAW4	LAW4 Sed Ls	I.s	Ma	10	100 17c	17c	46	42	Dry	TBM 11TC		16TC		ICTri	ICTri 3-1/2" x 2-1 2" x 3/4"

ROCK, OPERATING DATA, A MUCK SIZE RANGE, MDN T-M3 Deere AD 646 (10-1966) Interred from D U

FIGURE 3-4

3-15

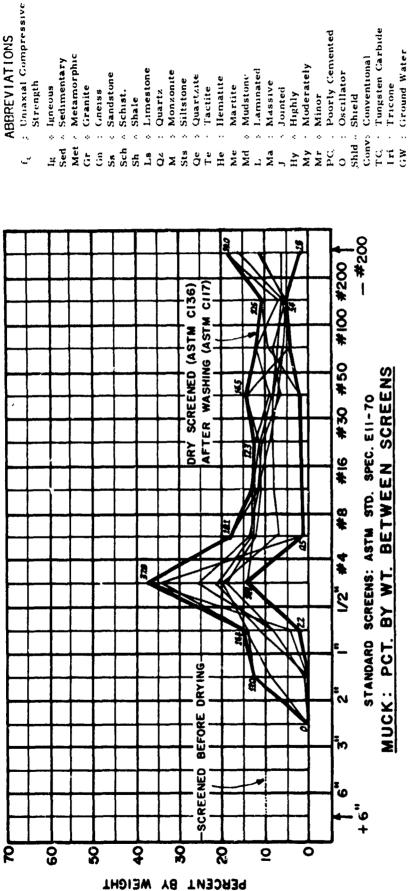
: Uniaxial Compressive Tungsten Carbide Poorly Cemented ABBREV I AT I ONS lig s lipneous
Sed s Sedimentary
Met s Metamorphic
Gir s Granite
Gin s Ginesis
Ss sandstone
Sch s Schist.
Sh s Shale
Ls s Limestone
Qz s Quartz
M s Monzonite
Sts Siltstone
Qe s Quartzite
Te Tactite
He Hematite
Md s Martite
Md s Moderately
My s Moderately
My s Moderately
Mr s Minor
DC s Oscillator Conventional Strength Shield Shld Conv. - #200 #100 #200 #30 #50 BY WT. BETWEEN SCREENS STANDARD SCREENS: ASTM STD. SPEC. EII-70 215 MUCK: PCT. 2. 9 8 8 \$ 8 9 0 PERCENT BY WEIGHT

Í		ROCK	\		(ROCK	HAR	HARDNESS			M	MACHINE CUTTERS	CULTER	S	
NO NO	CI.ASS	TYPE	CLASS TYPE STRUCT. K LBS	K LBS	γ o		SHORE	SHORE SCHMIDT G, W. METHOD DISC ROL'R DRAG CONE	G, W.	EXCAV METHOD	DISC	ROL'R	DRAG	CONE	MAX. SIZE OBSERVED
MILI	Sed Ls	Ls	My J 36	36	85	991		90	Mr	TBM 26**	56≈⊭			_	2" x 1" x 1/2"
MIL2	Sed I.s	I.s	My J 36	36	85	166		50	Mr	TBM 26*.	26*.			1	3" x 2" x 1/2"
Q1, 1	Met Sch	Sch	7	1.1	30	165		37	Mr	TBM 36:::	36:::				2" x 1" x 1/2"

Ground Water

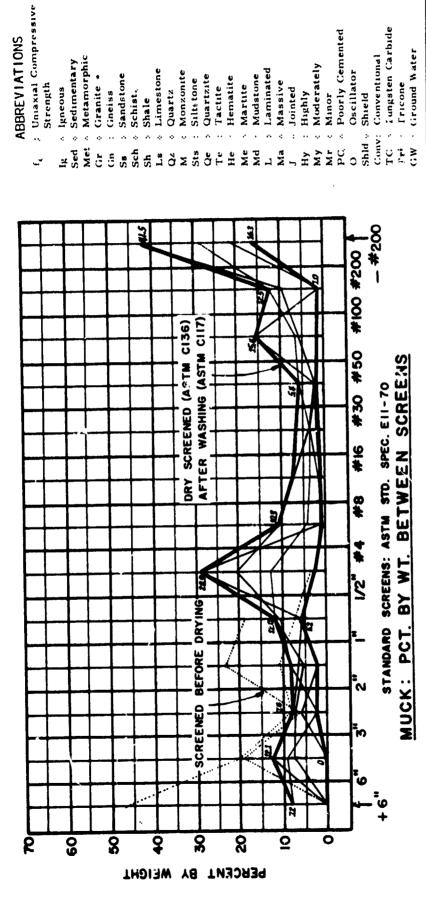
Inferred from D. U. Deere AD 0.46 610-1966 Trip'e Disc

ROCK, OPERATING DATA, & MUCK SIZE RANGE, MDN T-M4 FIGURE 3-5



CLASS TYPE STRUCT KLBS % PCF SHORE *SCHMIDT G. W. BY Met GrGh Hy J 9 10 174 45 Mr Sed S. PC 2 50 142 Mr Met Iç Gr My J 18 90 167 S5 Mr Ig GzM My J 32 92 165 S5 Mr Ig GzM Hy J 15 (E) 86 137 S0 Dry Ig Gr My J 18 90 147 S5 Mr			RCCK				ROCK	HARDNESS			M	MACHINE CUTTERS	CUTTE	RS	
Met GrCh Hy J 9 10 174 45 Mr TBM Sed Sed 142 30 Wet Shld. Iç Gr My J 188 90 167 55 Mr TBM Ig Gr My J 32 92 165 55 Dry RBM 27 Ig QzM Hy J 15 (E) 86 137 50 Dry RBM 11 Ig Gr My J 18 90 1<7 55 Mr TBM 11	IDENT NC.	CLASS	TYPE	STRUCT	-		PCF	*SCHMIDT		EXCA V METHOD		ROL'R	DRAG	CONE	MAX. SIZE OBSERVED
Sed S. PC 2 50 142 30 Wet Shld. Ig Gr My J 18 90 167 55 Mr TBM Ig Gr My J 24 90 160 55 Mr TBM 27 Ig QzM Hy J 15 (E) 86 137 50 Dry RBM 11 Ig Gr My J 18 90 1<7	CL.1	Met	CrCh	Hy J	٥	07	174	45	Mr	TBM		18TC		1-TCTri	1-TCTr1 1-1/2" x 2-1/2" x 3/4"
Ig Gr My J 18 90 167 55 Mr TBM Ig Gr My J 24 90 160 55 Mr TBM TBM Ig Q2M My J 15 (E) 86 137 50 Dry RBM 11 Ig Gr My J 18 90 1 7 55 Mr TBM 11	SF2	Sed	S°	PC	2	50	142	30	Wet	Shld.	Sir	igle Ripp	er Toot	h	3, x 2, x 8"
Ig Gr My J 24 90 160 55 Mr TBM Ig Q2M My J 32 92 165 55 Dry RBM 27 Ig Q2M Hy J 15 (E) 86 137 50 Dry RBM 11 Ig Gr My J 18 90 1<7	VAST2	ı,	Gr	My J	87	06	167	55	Mr	ТВМ		23.TC		2TC	1" x 1" x 1/2"
Ig Q2M My J 32 92 165 55 Dry RBM 27 Ig Q2M Hy J 15 (E) 86 137 50 Dry RBM 11 Ig Gr My J 18 90 ,<7	V, ST4	Ig	J.	My J	24	90	160	55	Mr	ТВМ		27.T.C		2TC	1-1/2" x 1" x 1/2"
Ig QzM Hy J 15 (E) 86 137 50 Dry RBM 11 Ig Gr My J 18 90 1<7	LKS	lg.	MzQ	My J	32	26	165	55	Dry	RBM	22				2-1/2" x 4" x 3/4"
1g Gr MyJ 18 90 147 55 Mr TBM	LKt	Ig	OzM	Ну Ј	15 (E)	86	137	50	Dry	RBM	11				2" x 3-1/2" x 1-1/4"
	NASTI	Ιg	Gr	My J	18	06	157	55	Mr	TBM		23TC		2TC	1 × 3/4 · × 1/2

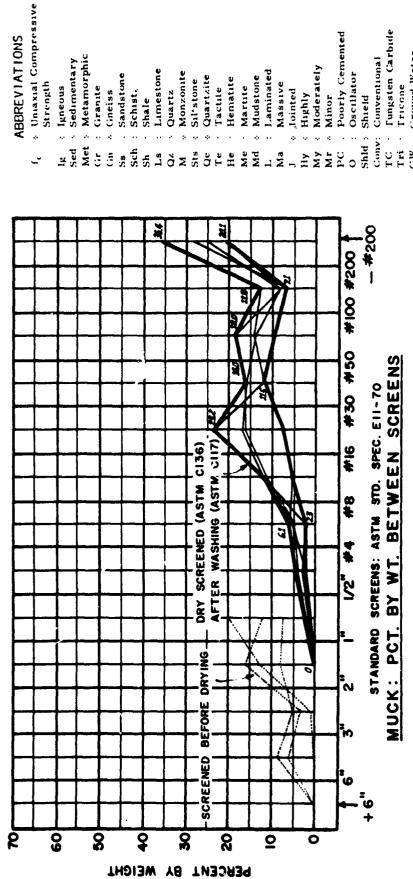
ROCK, OPERATING DATA, & MUCK SIZE RANGE, MDN T-M5, S5 FIGURE 3-6 Inferred from D. U. Deere AD 646 619-1966



		ROCK				ROCK	HAR	HARDNESS			MA	CHINE	MACHINE CUTTERS	s	MAX SIZE
IDENT NO	CLASS	TYPE	CLASS TYPE STRUCT. K LBS	fc in K LBS	ROD DUW		SHORE	SHORE *SCHMIDT G. W. METHOD	G. ₩.	METHOD		ROL'R	DISC ROL'R DRAG CONE	CONE	OBSERVED
KMI	Sed Md	Md	Ma	=	06	141		Ç	Dry	TBM			+0TC		36" x 14" x 8"
MB1	Met	HeMe	Met HeMe LHy J	7	0.7	207		82	Dry	TBMO			278TC		24" x 18" x 8"
LAYI	Sed Ss	Ss	Ma	13	84	150		47	Dry	ТВМ	30 including 1 triple disc	ng 1 trig	ole disc		4" x 4" x 1/2"
NAVI	Sed Sts	Sts	Ma	2	70	142		25	Dry	ТВМ	6TC+30		32TC		6" x 5" x 2"

ROCK, OPERATING DATA, & MUCK SIZE RANGE, MDN T-M6 *Inferred from D. U. Deere AD 646 610-1966

FIGURE 3-7



Sedimentary Metamorphic

Granite

Strength

Igneous

Limestone

Sandstone

Schist,

Shale

Monzonite

Quartz

Quartzite

Tactile

Silbstone

		ROCK		ڊ پ	a Ca	ROCK		HARDNESS		A 4 0 A 4	4M	MACHINE CUITERS	CUITEE	SS	
NO.	CLASS	TYPE	CLASS TYPE STRUCT. K LBS	K LBS	, r	PCF	SHORE	SHORE *SCHMIDT G. W. METHOD	ج.	METHOD	DISC	ROL'R	ROL'R DRAG CONE	CONE	MAX. SI/E, OBSERVED
NAV2	Sed	Ss	Э	1	09	117		25	Dry	TBM 6TC+30	6TC+30		32TC		5" x 2" x 1"
WNG1	Sed	Ss	ъс	1	30	125		20	Wet	TBM			72TC		14" x 4" x 4"
WNG2	Sed	S,¢	PC	1	30	125		20	Wet	Conv					18 ' × 10" × 4"
SFI	Sed	Ss	PC		0-35 113	113		02	Wet	Shild.	Sir	Single Rippor Tooth	vr Toot	æ	5" x 4" x 3"

Fungsten Carbide Tricone

Conventional

Poorly Cemented

Oscillator

Moderately

Minor

Laminated

Massive

Mudstone Hematite

ROCK, OPERATING DATA, & MUCK SIZE RANGE, MDN T-C7, M7, S7 FIGURE 3-8 Inferred from D. U. Deere AD 640 610-1966

MDN applicability to equipment selection is rated only on muck characteristics, and would be subject to constraints imposed by such factors as tunnel size, grade and length, equipment and power cost and availability, and environmental considerations in any final analysis.

Unitized systems in common use include Conventional Rail, Side Rail, and Free Vehicles.

Conventional rail systems capabilities and advantages include:

Hauling capacities can be varied by the addition or removal of cars or trains.

Materials, supplies and personnel can be transported by the system.

Easily adaptable to automatically controlled operation.

Loading and dumping can be done rapidly.

Track extension is relatively simple.

System constraints include:

The large percentage of tunnel cross section which is occupied by equipment.

High speeds needed for short cycle time.

Ideal road bed and track conditions are necessary if delays cannot be tolerated.

Passing tracks are required in long tunnels.

A secondary system or assisted haulage needed if vertical grade is over 4%.

Supply of materials required for system extension is a major operation at high advance rates.

Small clearances, high speeds, and massive moving equipment combine to produce long delays and serious injuries in event of accidents.

Combustion products complicate ventilation unless vehicles are powered electrically.

Conventional rail systems are applicable to any of the MDN's so far developed. Special cars would be required for high speed operations with very wet muck, and special dumping facilities with MDN's 6 and 7.

Siderail systems capabilities and advantages include:

Hauling capacities can be varied by the addition or removal of units.

Materials, supplies and personnel can be transported by the system.

Automatically controlled operation.

Loading and dumping can be done rapidly.

Can be used on much steeper grades than conventional rail systems.

Vertical and horizontal guidance tends to reduce frequency of derails and other accidents.

System constraints include:

Power units for side rail systems require electrical bus bars to be extended with the track.

The small size of units in current use limits haulage capacity, and the number of power units can result in maintenance problems and delays.

Continuous bus bars may be a personnel hazard.

MDN's 1 through 7 could be transported by this system. Problems in unloading cars can be expected from MDN's 6 and 7 if wet, due to the high percentage of fines.

Free vehicle capabilities and advantages include:

System capacity can be varied by the number of vehicles, or by change in speed.

Materials can be transported inbound and outbound.

Guideway for operation is not required.

'System constraints, are:

Tunnel size limits use of free vehicles in long tunnels unless turnouts are provided.

Roadway must be well graded and maintained to support weight and speed of vehicles.

Present design of vehicles uses excessive amounts of tunnel volume per ton of capacity, and does not provide the ability to operate in both directions equally well.

Inability to climb grades of 8 - 12% at adequate speeds.

Operator required for each vehicle.

Small clearances, high speeds, and massive equipment combine to produce long delays in case of malfunction, and serious injuries in event of accident.

Combustion products complicate ventilation unless vehicles are powered electrically.

MDN's 1 through 5 can be transported by free vehicles. Excessive tire wear could be expected in the MDN 1 and 2 range, due to angularity and abrasiveness of these materials. This system may not be practical for sites producing muck in the MDN 6 and 7 range because of traction and roadbed maintenance problems.

Semi-continuous systems in common use are belt conveyors, hydraulic, and pneumatic pipeline systems.

Belt conveyor capabilities and advantages include:

Possible installation overhead or at sides of tunnel leaves floor space for other uses.

Capacities can be increased by changing belt speed.

Conveyors can go up or down slopes to 22°.

Constraints on the system include:

Supplementary transportation which must be provided for incoming materials, and personnel.

Delays inherent as the conveyor is extended from a temporary to a semi-permanent installation.

All MDN's can be transported by conveyors. Excessive belt damage and wear can be expected in the 1 and 2 MDN range, because of piece size and shape, unless the material is crushed prior to being placed in the system. In the MDN 6 to 7 range, through a wide range of water occurrence, considerable material will stick to the belt causing excessive cleaning problems. In the entire MDN range it is mandatory that the water content be below the point where the muck will slip or flow on the belt, or overflow the sides.

Hydraulic pipeline capabilities and advantages include:

Capacities adequate for the tonnage from any tunnel in the foreseeable future.

Pipelines use very little space in the tunnel.

Especially adaptable to very wet sites and to hydraulic excavation systems.

Adaptable to any grade, including vertical.

System contraints are:

Capacity to handle plus 1" to plus 2" material through centrifugal pumps has not been demonstrated in field usage.

Crushing or scalping equipment for through-centrifugal pump systems, or lock-feed equipment for alternate designs may cause congestion in the near face area.

Large amounts of water are required.

Required electrical power may be difficult to provide for long tunnels in remote areas.

Dewatering, recirculation, and muck disposal systems may be elaborate.

For high advance rates, methods of advancing pumping units and pipelines must be developed.

The heat load from large electrical installations may be difficult to dissipate.

System malfunctions may be hazardous to personnel.

MDN 7 is best suited for pumping because of the low percentage of plus #4 material, and a high fines content. Preliminary screening and/or crushing would be needed for transporting all MDN's by a through-centrifugal pump system.

Pneumatic pipeline capabilities and advantages include:

Pipelines use very little space in the tunnel.

Adaptable to any grade, including vertical.

System constraints are:

Power requirements appear excessive.

Muck must be relatively dry.

Crushing or scalping equipment must be used if pieces are too large for system.

Pipe wear and maintenance may be excessive.

Secondary transportation must be provided for materials and personnel.

Methods of advancing blower units and pipe must be developed.

Dust at the discharge or from malfunctions may be hazardous to personnel.

MDN 7 is best suited for pneumatic systems because of the low percentage of plus #4 material and the high fines content. Preliminary screening and/or crushing would be needed for transporting all MDN's.

4. DOD IMPLICATIONS

Other investigations have shown that the data accumulated under the program are nonexistant in usable form elsewhere. While some tunnel boring machine (TBM) manufacturers and operators consider muck size an indicator of cutter efficiency, changes are noted during informal inspections at the machine, and are seldom recorded except as showing a need for cutter replacement. A few screen analyses have been run, but results normally are not made available outside of the manufacturer's organization.

The choice of transportation systems usually is based on availability and contractor familiarity with the equipment used at other sites. In some cases, the choice has been completely unsuitable for the muck produced. This has resulted in delays and additional expense which may be avoided by using the information collected under this program.

Previous investigations also have indicated that major modifications of conventional equipment, or design of completely new systems, will be necessary to dispose of the muck from the high speed excavation systems predicted for the future. Muck characteristic data is a requisite as a basis for the engineering design of system improvements, and should be used to indicate the areas in which research and development of new methods will be most productive.

5. IMPLICATIONS FOR FURTHER RESEARCH

The planned program for the first year's work provided for a third of the samples to be taken in each of the "High" and "Medium" strength rock classifications, and for the remainder to come from "Low" and "Very Low" classifications. This ratio was maintained, and four additional samples were taken from operations in rock classified "Very High" in strength. Lithologic classifications sampled to date include examples of relatively coarse grained igneous rocks, four types of metamorphic rocks, and three types of sedimentary rocks. Both conventional and machine operations were sampled in all categories except the metamorphic rocks. Rock types not yet sampled, including the stratified volcanic and the finer grained igneous rocks, should be sampled to provide data on these formations, and data on excavation by different methods in rocks previously sampled should be collected to provide comparative data.

The engineering and muck properties of rocks of the same lithologic type may vary over a wide range. To make the MDN concept a useful tool in the rapid excavation program, every opportunity should be taken to obtain data from as many new sites as possible in order to confirm a previous assignment of an MDN to a rock type, or to obtain data indicating that another category is justified.

Nearly one-third of the operations sampled were conventionally driven tunnels. While the major interest is in mechanical excavation, the most rapid progress is being made by conventional and shield methods. Therefore, it is believed that this ratio should be maintained to provide data from high speed materials handling systems.

Statistically, the reliability of data and conclusions is a function of the sampling frequency. For this reason, at least three specimens of the same rock have been tested whenever possible to provide engineering property information. Less than fifteen percent of the operations sampled have been resampled to improve the confidence level of the muck characteristic data. Subject to site availability, resampling is recommended.

Reference to other rock property research programs indicates that Young's modulus and Poisson's ratio may be important engineering properties to correlate with muck characteristics. Both can be determined from stress-strain data taken during compressive testing. Provision for collection of these data in the 1972 program has been recommended.

To provide other data which may be highly significant, provision for Schmidt hardness tests on rocks and abrasiveness tests on muck has been recommended as part of the continuing research.

Unusual rock breaking techniques now under development, such as the electron beam and the water cannon, may become standard practice in the future. Sampling muck from tests of these methods whenever possible is recommended.

6. SPECIAL COMMENTS

No equipment has been purchased or developed, nor has any invention been made in the course of the work performed under this contract.

GLOSSARY

ASTM	American Society	PMSRC	Dittahunah Minima
	for Testing	1-MB1(C	Pittsburgh Mining
	and Materials		and Safety Research Center
ВМ	Beam	POT.	Potential
CFM	Cubic feet per minute	PCF	
COMPR.	Compressed	PSI	Pounds per cubic foot
CONTIN.	Continuous	POI	Pounds per
CY	Cubic Yard	Rect.	square inch
DEG.	Degrees	REG.	Rectangle
DIA.	Diameter	RBM	Regular
DUW	Dry Unit Weight	RPM	Raise Boring Machine
Est, (E)	Estimated		Revolutions per Minute
FWD	Four Wheel Drive	RQD	Rock Quality
GPM	Gallons per Minute	C TT	Designation
HP	Horse Power	ST	Scoop Tram
HRS.	Hours	SPECIF.	Specific
IN.	Inch	STRNTH.	Strength
Inter.	Internal	TBM ·	Tunnel Boring Machine
K	Thousand	TC	Tungsten Carbide
LBS	Pounds	TCB	Tungsten Carbide
LT	Long Ton	m	Button
MDN	-	T	Tentative
W1D14	Muck Designation Number	T.	Ton
MAX	Maximum	V	Volt
Moist.	Moisture	VOL	Volume
MM	Millimeter	W/	With
NA.		WT.	Weight
NO.	Not Available	4	Foot
PCF	Number		Inch
PCF	Pounds per	#	Number
PCT	Cubic Foot	%	Percent
	Percent	(+)	Plus
PF	Powder Factor	(-)	Minus

APPENDIX A

TUNNEL LIST

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TUNNEL PROJECTS

Compiled by Holmes & Narver, Inc., Anahiem, California, under U. S. Bureau of Mines, Contract HO210013. Revised 1 January 1972

NORTH AMERICAN CONTINENT

PROJECT &	OWNER			1
LOCATION	OR AGENCY	SIZE	LENGTH	CONTRACTOR
MINERAL CREEK	Kennecott Copper	16'x16'	3,6 Miles	Fluor-Utah
DIVERSION TUNNEL	Corporation	Excav.	31 0 1411168	Engrg & Const
Ray, Arizona	Ray Mines Div.	15'x15'		Company
•	Hayden, Arizona	Lined	II.	. ,

Excavation by conventional methods. Formations include 14 rock classifications, predominantly quartitie, shale, diabase, schist, altered granite, porphyry and dacite. Core specimens exist.

Owner management has not approved core tosting or muck sampling.

LAKESHORE MINE	Hecla Mining 🕟	14'x14' 7500'	Hecla Mining
Casa Grande,	Company -	14'x18' 7500'	Coown force
Arizona	El Paso Natural	plus lovel	•
•	Gas	development	

The two 7500' headings are declines at a minus 150, currently at about 6200' slope distance from the portal. Levels are being developed at 900' and 1400' vertically below the portal. Formations include mylonite, quartitie, tactite, and quarte monzonite. A raise boring machine has started a series of holes to the development levels.

NAST TUNNEL	U.S. Bureau of	10' Dia.	3 Miles	Peter Klewit
Fryingpan Project	Reclamation			Sons Company
Merideth, Colorado	Denver, Colorado			, ,

A Wirth boring machine, modified by installation of shields and a new cutter head, has completed about 1 mile of tunnel from the outlet portal. Formations penetrated are predominantly granite, granite gneiss, granite porphyry, and granodiorite with compressive strengths from 18,000 psi to 24,300 psi. Rock is highly sheared in zones from a few feet to 400 thick.

TUNNEL PROJECTS (continued)

PROJECT & LOCATION	OWNER OR AGENCY	SIZE	LENGTH	CONTRACTOR
TONNER	The Metropolitan	81 Dia.	#1-45891	Up for bids
#1 and #2	Water District of	Lined	#2-19,360'	Feb. 1972
Brea, Cal.	Southern Calif.			

Expected to be a shield operation in low strength sandstone and siltstone. Geologic data and cores are available from the owner agency.

HUNTER TUNNEL	U.S. Bureau of	10'x10'	4.4 Miles	Granite
Fryingpan Project	Reclamation			Construction
Merideth, Colorado	Denver, Colorado			Company

A conventional operation in formations similar to the Nast tunnel. Lithologic and Engineering property data has been collected from the U.S. Bureau of Reclamation.

FOGGY BOTTOM-	W.M.A.T.A.	164-84	4,000'	S & M
ROSSLYN TUNNEL	Washington,	Dia.	each of	Constructors
Section C-4	D.C.	Finished	two bores	(E.W. Murphy)
Washington, D.C.				

Excavation by conventional methods in gneiss under the Potomac River. The schistose rock structure is reported to result in high shear attength and low compressive strength. Lithologic and Engineering property data has been collected from the W.M.A.T.A.

MT. GREENWOOD	Dept. of Public	10'-4" 1.8	8 Miles	S. A. Healy
TUNNEL	Works, City of	Diameter		
Chicago, Illinois	Chicago, Illinois			

A new Robbins machine is being assembled for operation in limestone, reported similar to that in the Lawrence Avenue tunnel.

TUNNEL PROJECTS (continued)

PROJECT & LOCATION	OWNER OR AGENCY	SIZE	LENGTH	CONTRACTOR
WHITE PINE COPPER CO. White Pine, Michigan	Copper Range Company, New York, New York	18'-1'' Diamete 18'x8½' Rect.	Various r	Tunneling by White Pine with own force

A Robbins machine has been operating in sandstone since 1969, is now passing through a conglomerate horizon to reach the overlying shale. An Atlas-Copco machine is operating in the shale. Normal drifting is conventional. Existing rock property data includes compression, Brazilian tensile, and Shore hardness test results.

NEVADA TEST	U.S.A.E.C. and	Various.	Reynolds
SITE	Defense Atomic	,	Electrical &
Mercury, Nevada	Support Agency (DASA)		Engineering Co.
•	Mercury, Nevada		,

Two conventional tunnels are operating. An Alpine Miner has been used on an experimental basis, and may provide an opportunity for comparison of the muck produced by the two systems. Formations are volcanic tuffs which vary from 600 to 4,500 psi in unconfined compressive strength. Engineering property data has been collected by the U.S. Geological Survey and by DASA.

NAVAJO IRRIGA-	U.S. Bureau of	20, 51	3 Miles	Fluor-Utah
TION PROJECT	Reclamation	Dia.		Engrg & Const
Farmington,	Denver, Colo.			Company
New Mexico				

A Dresser boring machine is operating in sandstone with an unconfined compressive strength of less than 1000 psi, is expected to reach an 8000 psi sandstone as the tunnel advances.

SECTION 35	Kerr-McGee	10'x10'	Various	Kerr-McGee
URANIUM MINE	Corporation	and		own force
Grants (Ambrosia		81x81		
Lake)New Mexico				

An Alpine Miner is operating in siltstone development headings, is expected to reach an underlying sandstone in which normal operations are conventional.

TUNNEL PROJECTS (continued)

PROJECT & LOCATION	OWNER OR AGENCY	SIZE	LENGTH	CONTRACTOR
CURRANT & LAYOUT TUNNELS Strawberry Aqueduct, Heber City, Utah	U.S. Bureau of Reclamation Denver, Colorado	10'-4" Dia.	Combined Length 4.9 miles	S. A. Healy

A Robbins boring machine has been operating in sandstone. Existing logs of 13 drill holes show lithology. Compressive strength test results, varying from 5,000 psi for a shale to over 38,000 psi in the conglomerate, have been provided by the Bureau of Reclamation. This tunnel has been stopped incefinitely pending provision of additional funds.

CONTR. 843	City of	11'-2"	50001	W.J. Lazynski
SEWER TUNNEL	Milwaukee	Dia.		Company
Milwaukee, Wisc.				* =

A Jarva boring machine is being rebuilt before starting a new contract on a lateral to the present tunnel in 1972.

GOLDEN GOOSE II	Western Nuclear	8'x10'	Develop- :	Owner
URANIUM MINE	Inc.		ment Drifts	Operated
Jeffrey City, Wyoming				

An Alpine Miner equipped with a Serpentix conveyor is driving mining headings in soft sandstone. Conventional drifts are also being driven in similar formations.

NEW YORK CITY,	Dept/Public	ll' Dia.	9 2 00'	Perini-B & R-
N.Y., Contract #13	Works, NYC			G.H. Ball-S & M
				Constructors, IV

Scheduled to start in January 1972 using a new Jarva boring machine. Formation is mica schist; compressive strength 15,000 to 30,000 psi. Cores and rock test data are reported to be available from the owner.

APPENDIX IS

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MAST-2	H-2
NAST-3	B-3
NAST-4	13-4
CAN	B-5
H-1	B 6
H-2	B-7
1.1.	8-8
LK-2	3-9
List + 5	2-10
LK-6	B-11
CL-1	B-12
LK-3	B-13
LK-4	B-14
MB-I	B-15
QL-1	3-16
5-1	3-17
7 00 2	B-18
11-3	3-19
11-4	8-20
LAW-2	13,-21
LAW-3	8-52
I.A W - 4	E-23
Mil1	13-24
MIL-2	B-25
1-XX-1	B-26
NAV-1	B-27
NAV-2	B-28
WNG-1	B-29
WNG-S	B-30
SF-1	B-31
SF-2	. B-32
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ROCK PROPERTIES IGNEOUS: GRANITE. MASSIVE. MAJOR QUARTZ AND FELDSPAR. MINOR DARK MINERAL CONTENT.		H	17.9 12.2 10.3		AI AI AI		15.78	ANGLEZHEPOSE 10 IN UROP DEGREES AT 0.9 PCI MOIST	36
ROCK PROPERTIES IGNEOUS: GHANITI MAJJR QUARTZ ANI MIKOR DARK MINEI		PCT(*)6 **** In.size 6in.	1:1	OF FRACTIONS BETWEEN SCREEN SIZES	IV	LIOUID LIMITS PCT	16.2	ANGLE/REPOSE 1 IN DROP DEGGEFF AT	•
IDENTIFICATION GRAVITE ADIT SAMPLE NO GA-1		MOISTURE PCT	6	E OF FWACTIONS		POT VOL CHANGE (-)0.0°4 IN.SIZE		IN.5126	38
KEY 10EN1 5 GRAY1 SAYPL GA-1		MUCK DATA DOY UNIT #I PCF	114	SHAPE		, TC4	•	(-)0.75 SPECIF GRAVITY	5.59

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	PCT (-) NO200 3.4	SP.SP-LEROID		O IN. IER AT HOIST	
MA A	00 NO200	A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SP-4EROID AI AI AI AI AI AI AI AI	TOUGHNESS INDEX 0.23	SIZE(-)2.0 ANGLE INTER FRICTION DEGREES AT 2.2 PCT HOI	\$
SHORE NON SCHMIDT	M030 M050 N0100	IC I=IRREGULAR AI AI	FLOW INDEX	BULK BULK DENSITY' PCF AT PCT,M01ST	4
PCT SHORE EST NA .	SCREENS	PLATY C=CUB	-) 0.056IN	APPARENT COMESION PSF AT PCT MOIST	4
COMPR STRUTH KPSI 32	BETWEEN SCRE NOS NO 5.7 4.3	R-ROUNDED P= A1 A1	:IZE(-) 0.054 - PLASTIC INDEX PCT 1.0		
ya 24 € 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	F BY WEIGHT ZIN. NO. 12.9	=Subangular	erg Limits Shrimkage Limit PCT 13.4	SIZE(-)2.0 IN ANGLE/SLIDE STEEL PLATE DEGREES AT 1.3 PCT 40IST	8
RAY• FINE JOINTED• MOS OF AND GNEISS•	. ZIN. 11N. 1.	_	PLASTIC. SHRIWKAGE PLAILINITSSIZE(-) PLASTIC. SHRIWKAGE PLINIT IN PCT PCT 17.0 LD.4 LD.4	ANGLE/REPOSE 10 IN UROP DEGREES AT 1.3 PC1 HOIST	37
RCUK PROPERTIES IGNEOUS: GRANITE, GRAY, FINE GRAINED, MODERATELY JOINTED, WITH 1.5 TO 2 FT BANDS OF LIGHT TAN PEGMATITE AND LAMINATED GRANITIC GNEISS.	61N. 31N. 21N. 6.8 12.7 13.	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	LIMITS PCT 18.0	is T	
	JRE PCT(+)6 IN-S1ZE 14-3	CTIONS BETWEE	3 21	ANGLE/RE 1 IN DR DEGREES 1.3 PCT	04
IDENTIFICATION MUNTER SAMPLE NO H-1	MUCK DATA DRY UNIT MOISTURE WI PCF PCI 107 3.4	SHAPE OF FRA	POT VOL CHANGE (-)0.056 IN.S	(-)0.75 IN.SIZE SPECIF GRAVITY	2.10

#12

HORE NON SCHULDT	4
HARDN	\$
SHORE	¥
PCT EST	•
COMPR STRNIH KPSI	33
P W P CF	3
ROCK PRUPERIIES IGNFOUS: GRANITE GRAY. GNEISSIC. MUGERATELY JOINTED.	
KEY IDENTIFICATION 7 HUNTER SAMPLE NO	7
KEV 7	

PCT (-) N0200	3.3
*	1.1
	1.3
330 NO	19.3 11.6 9.3 4.8 4.2 4.5 3.4 1.3 1.1
EENS	4.5
WEEN SCRINGS	4.2
MT 86T	•
BY WEIGIN. NO	9.3
CENT (11.6
N. 113	19.3
IN. ZI	11.7 i8.2
61N. 31	11.7
PCT(+)6 IN-SIZE	7.3
MOISTURE PCT	3.4
MUCK DATA ORY UNIT WT PCF	109

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A MANGULAR SASUBANGULAR RAROUNDED PAPLATY CACUBIC INTRREGULAR EMELONGATED SPASPHEROID

	FLOW TOUGHNESS IMDEX INDEX	*0*0	SIZE(-)2.00 IN. ANGLE INTER FRICTION DEGREES AT 2.6 PCT HOIST	;
¥				พั
Y.	FLOW INDEX	3.20	APPARENT BULK COMESION DENSITY PSF AT PCF AT 2.6 PCT MOIST 0.0 PCT MOIST	105
AI	i		ROISI	
¥	-) 0.056IN. PLASTICITY INDEX PCI	0.15	IN APPARENT COHESION PSF AT IST 2.6 PCT M	30
7	, SIZE (_		
AI AI	PLASTIC. SMRINKAGE . PLASTICITY LIMIT LIMIT INDEX PCT	11.00	ANGLE/MEPOSE ANGLE/SLIDE IN IN UROP STEEL PLATE UEGREES AT DEGREES AT 3.8 PCT MOIST	38
ΑΙ	C.		RIAL S OSE P T OIST	
Y.	PLASTIC LIMIT PCT	17.95	ANGLE/KEPE ANGLE/KEPE 10 IN UROI DEGREES A	35
¥	LIGUID LIMITS PCT	18.10		
A1			ANGLE/REPOSE 1 IN DROP DEGREES AT 3.8 PCT MOIST	38
	POT VOL CMANGE (-)0.056 IN.SIZE	•	(-)0.75 IN.SIZE *SPECIF SPECIF GRAVITY DEGFEES AT 3.8 PCT HOIST	2.60

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		PCT C- NO200	•	A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID				O IN.
1		0020N		7ED S		•		12.0 INTER ION ES AT
		NO N	-	LONGA		NESS	•	SIZE(-)2.0 ANGLE INTI FRICTION DEGREES A
2		000	0.1	E		TOUGHNESS	0.30	
		M030 N050 N0100	0•3	REGUL/	¥.	•		
2	<u> </u>	NO 50		1=1R		FLOW INDEX	96	EX EX EX F AT PCT
•	S	9	0.3	CUBIC	A	28	3.90	
		2	*	Ğ ≱	4			IT IN IN MOIST
EST	3	ER CENT BY WEIGHT BETWEEN SCREENS IIN. 1/21M. NO4 NO8 NO16		P=PLA	I V	PLASTIC - SHRINKAGE - PLASTICITY FLOW INDEX INDEX PCT		APPARENT COHESION PSF AT
		EN SC	0.5	MOED		PLAST INDEX PCT	0.12	
1	S	BETWE	1.0	R*RQ	¥	S12E (•		INSI
		EIGHT NO4		GUL AR	¥	IITS AGE		(~)2.0 IN ANGLE/SLIDE STEEL PLATE DEGREES AT .8 PCT MOIST
•	162	EY W	2.0	SUBAN		RG LIM SHRINA LIMIT PCT	17.69	SIZE(-)2.0 ANGLE/SL STEEL PL DEGREES 0.8 PCT
		ER CENT	3.8	LAR Si	¥	TERBE!		\$12E
		PE	2.0	= ANGU	¥I	IC .	φ.	ANGLE/HEPOSE ANGLE/HEPOSE 10 IN UROP DEWREES AT 6 PCT HOIST
		218	6.3		I	PLASTI LIMIT PCT	17.98	ANGLE/MEPOS 10 IN UROP 10 ECHEES AD 10.8 PCI HOI
:		6IN. 3IN. 2IN. 1	13.8	EN SIZ	I V	:		
GKAINEU FURPHINI.		• 0		SCREI		LIQUID LIMITS PCT	18.10	ANGLE/REPOSE 1 IN DROP DEGREES AT 0.8 PCT MUIST
		PCT (+)6 IN-SIZE		:TWEEN	•••		38.	ANGLE/REPOSE 1 IN DROP DEGREES AT 0.8 PCT HUIS
ı			66.8	ONS BI	¥	2E		ANGLE/REP 1 IN DROP DEGREES A
		MOISTURE PCT		SHAPE OF FRACTIONS BETWEEN SCREEN SIZES		4ANGE In.Size		3215*NI
2			•	L 0		*		75 IN. 17
SAMPLE LK-1	•	C DATA C UNIT PCF	102	SHAPE		POT VOL (•	(-)0.75 SPECIF GRAVITY
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LK-2

	PCT (-) NO200 1.3	SP=SPHEROID		O IN. ITER I A I HOIST	
MA AM	SCREENS	A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLAIY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID AI AI AI AI AI AI AI AI	TOUGHNESS INDEX 0.058	SIZE(-)2. ANGLE IN FRICTION DEGREES	æ
SHORE MON SCHMIDT	NOSO NO3	BIC I=IRREGULA! AI AI	FLOW INDEX 6.2	BULK BENSITY PCF AT B.0 PCT MOIST	9.79
Rob PCT SWORE EST NA	1.3 1	#PLATY C=CUB	61N. CITY	RENT ESION AT PCT MOIST	210
COMPR STRNTH KPSI 28	BETWEEN SCRE NOS NC 2.0 1.8	R=ROUNDED P. AI AI	SIZE(-) 0.05 PLASTI INDEX PCI 0.36	NI NI 15	
ORY WI PCF	NT BY WEIGHT 1/21N• NO4 i 5•3	S=Subangular AI	ERG LIMITS SHRINKAGE LIMIT PCT 17.29	SIZE(-)2.0 IN ANGLE/SLIDE STEEL PLATE DEGREES AT 4.7 PCT MOIST	33
ROCK PROPERTIES IGNEOUS: BIOTITIC QUARTZ HONZONITE. FINE TO NEUIUM GRAINED PORPHYRY. WITH MINOR STEEPLY INCLINED JOINIS.	31N. 21N. 11N.		PLASTIC SHRINKAGE PLASTICITY LINIT LIMIT NDEX PCT PCT PCT 19.14 17.29 0.36	73 E	75
ROCK PROPERTIES IGNEOUS: BIOTITIC GUAKTZ MONZONITE. FINE TO MEDIUM GRAINED PORPHYRY. WITH HIS STEEPLY INCLINED JOINIS.	PCT(+)6 IN.SIZE 49.1	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	LIQUID LIQUID PCT PCT 20.50	ANGLE/REPOSE ANGLE/REPOSI 1 IN DROP 10 IN DROP DEGREES AT DEGREES AT 4.7 PCT MOIST 4.7 PC1 MOIS	£ 4
KEY IDENTIFICATION 9 LK Sample NO LK-2	MUCK DATA DRY UNIT MOISTURE WI PCF PCT 103 1.6	SHAPE OF FRACT	POT VOL CHANGE (-)0.056 IN.SIZE 0	(-)0.75 IN.SIZE SPECIF GRAVITY	2.73

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LK-5

KEY 10	IDENTIFICATION LK SAMPLE NO	ICATION NO	ROCK PROPERTIES IGNEOUS: BIOTITIC OUARTZ MONZONITE: FINE TO MEDIU GRAINED PORPHYRY	TIES OTITIC (FINE TO PHYRY	IC QUARTZ TO MEDIUM	_		DR. PCF	COMPR STRNTH KPSI		ROD PCT S	HORE	SHORE MOH SCHMIDT	SCHAIL	• •	
	LK-5						ria C		35	.	26	₹	4	42		,
¥ 0 ¥	MUCK DATA DRY UNIT WT PCF	MOISTURE PCT	PCT(+)6 •		21N.	PER (ENT BY 1/2IN	6in. 3in. 2in. 1in. 1/2in. NO4	BETYEEN NOB	N SCREENS NO 16		000	NO50		**************************************	PCT (-) NO200
	76	16.8	0.0	0.0	0.0	13.0 14	14.0	20.0	7.0	0.		8	9		5.0	11.0
	SHAPE OF	DF FRACTIO	FRACTIONS BETWEEN SCREEN SIZES	IEEN SIZ		INGULAF	80S#\$ \$	ANGULAR	R=ROUN	0E0 PæP	LATY (2=CUBIC	1= IRRE(GULAR E	A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID	SP=SPHEROIO
					9	I	m	ï	<	<	<	⋖	<			
	POT VOI	POT VOL CHANGE (~) IN.SIZE	E LIGUID PCT	•	PLASTIC LIMIT PCT	7	RBERG LIN Smrin Limit Pct	NTTERBERG LIMITSSIZE(-) SMRINKAGE LIMIT PCT	S12E (-) P I	LASTIC NDEX CT	IN.	•	FLOW	TOL	FLOW TOUGHNESS INDEX	
	(-) SPECIF GRAVITY	IN.512E	ANGLE/REPOSE 1 IN DROP DEGREES AT PCT MOIST	ANC	ANGLE/MEPOSE 10 IN UROP DEGREES AT PCI MOIST	4. IS	SIZE (-) ANGL STEE DEGG	(~) ANGLE/SLIDE STEEL PLATE DEGREES AT PCT HOIST	NI ST	APPARENT COHESION PSF AT PCT	APPARENT COMESION PSF AT PCT MOIST	BBU DE PC	BULK BENSITY PCF AT PCT, HOIST	.015T	SIZE(+) ANGLE INTER FRICTION DEGREES AT PCT MOI	IN. ITER AT HOIST

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		PCT (-) N0200	16.0
SHORE HOH SCHMIDT		**************************************	0.0
HARDM HOH NA		NO50	8.0 7.0
		N030	
R PCT	CIMENS ONG IURING ION.	N SCREENS	11.0 11.0
COMPR STRNTH KPSI EST 15	TEST SPECIMENS BACKE ALONG JOINTS DURING PREPARATION.	HT BETWEE	19.0 12.0
94 PCF		r by weig /2in. no	19.0
_ 100		PER CEN' 11N. 1	1.0 9.0
C GUARTZ TO MEUIUM • FREGUEN IS•		. 21N.	0.0
MOCK PROPERTIES IGNFOUS: BIOTITIC QUARTZ MONZONITE: FINE TO MEDIUM GRAINED PORPHYRY: FREGUENT FLAT ANGLEO JOINTS:			.0
MOCK PIGNEOU MONZON GRAINE		PCT (+)6 IN-SIZE	0.0
ICAT 10N		IT MOISTURE PO	16.8
II LK SAMPLE NO LK-6		MUCK DATA DRY UNIT N	06
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SHAPE OF FRACTIONS BETWEEN SCREEN SIZES AVANGULAR SASUBANGULAR RAROUNDED PAPLATY CACUBIC INTRREGULAR EMELONGATED SPASPHEROID

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PLASTICITY FLOW TOUGHNESS INDEX INDEX PCT POT VOL CHANGE (-) IN.SIZE

SIZE(-) IN.
ANGLE INTER
FRICTION
DEGREES AT
PCT MOIST BULK BENSITY PCF AT PCT MOIST IN APPARENT COMESION PSF AT PCT NOIST ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOIST ANGLE/KEPOSE ANGLE
10 IN DROP STEEL
DEGREES AT DEGRE
PCT MOIST P ANGLE/REPOSE
I IN DROP
DEGREES AT **IN.S12E** SPECIF GRAVITY

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SHORE NOH SCHMIDT	4
• • HARDM	ž
SHORE	¥
Pot FST	•
COMPR STRNTH KPSI	•
O M G	174
ROCK PROPERTIES HETAMORPHIC: GRANITIC GNEISS. HIGHLY METAMORPHOSED. HODERATELY TO HIGHLY FOACHLOSE.	CACLOREU MONLI SILLUTEDO
12 CLIMAX SAMPLE NO	į
KEY 12	

1.8
5.4
5.6
6.9
2.8.5
3.1 11.
37.8 10
0.0 4.8 37.8 18.1 11.2 8.5 6.8
0.0
0.0
8.8
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SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

			R IN.	
	IN FLOW TOUGHNESS INDEX	N	SIZE(-) ANGLE INTER FRICTION DEGREES AT PCT HOIST	¥
YI.			 IIY AT PCT, M01ST	
¥.	FLOW	. \$	BULK BULK DENSITY PCF AT	42
IV	IN		: 5	4
¥	STI	4	INAPPARENT COHESION PSF AT IST PCT M	
AI	SSIZE (-	*	IN E/SLIDE L PLATE EES AT PCT HOIST	
VI.	ERG LIMITS. SHRINKAGE LIMIT PCT	«	_1 M 62	¥
¥I	71ER8		5126	
	PLASTIC: SHRIMKAGE . PLA SIND PLASTIC: SHRIMKAGE . PLA IND PCT PCT PCT	4	ANGLE/KEPOSE ANG 10 IN UROP STEI 0EGREES AT DEG	4
	Liguld Limits PCT	4	ANGLE/REPUSE 1 IN (ROP DEGREES AT PCT HOIST	
	CHANGE In•S12E		IN.SIZE **** ANGL 1 IN DEGR	4
	POT VOL CHANGE (-) IN.SI	₹ 2	(-) II SPECIF GRAVITY	4 Z

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	PCT (-) NO200	۳ ٠	SP=SPHE			O IN.	ų
•••	NO100 NO200	••	A=ANGULAR S=SUBAWGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID		TOUGHNESS INDEX 0.06	SIZE(=)2.0 ANGLE INTER FRICTION DEGREES AT 0.4 PCT MOIS	7
SHORE HON SCHILLT		© •	EGULAR.	į		** #015T	117.8
HOH NA NA	NO50		1 = 1 RA	•	FLOW INDEX 5.50	BULK DENSITY PCF AT	.
SHORE NA	SCREENS	•	C=CU810	4	i i i	BUN BUN DEI PCI MOIST 0.0	
B E ST T ST T ST T ST T ST T ST T ST T S	REENS	1.2	Paplaty	I	D 0.056IN	PARENT RESION F AT	175
COMPR STRNTH KPSI 26	BETWEEN SCI NOS	1.6	OUNDED	VI.	PLAST INDEX PCT 0.33	INAM	٠
COMPR STRNT KPSI 26	HT 8€T!	5.8	A. A.	¥Ĭ.	S512E	IN 1DE ATE ATE NOIST	:
7 P CI	ER CENT BY WEIGHT IN. 1/2IN. NO4	6. 7	Subangu	¥.	ITTERBERG LIMITSSIZE(~) SHRINKAGE II LIMIT PCT I7.80	SIZE(-12.0 ANGLE/SLIDE STEEL PLATE DEGREES AT 1.5 PCT MOI	62
5 6 3	PER CENT 11N• 1/3	10.6	LAR S	¥	TTERBER S P	AL SIZE(
YERED UARTZITE ELY TO ASEDIMENTS ITE: NETITE AND SILICATES	6IN. 3IN. ZIN. 11	10.2	- VE ANG	A1		ANGLE/KEPOSE ANGLE/KEPOSE 10 IN UROP DEGREES AT	•
TEMLAYERE HEEN QUART DERATELY D METASED IT PYRITE, D MAGNETI VGE OF SIL	31N. 2	6 %	. S12ES	IV	PLASTIC LIMIT PCT 17.92	. < ~ 0 .	62
PERTIES HICE INTENTION BETWEEN THE MODERA ALTERED ME LACEMENT PY RITE AND MA RETO MEDIUM TO MEDIUM		17.4	SCREEN	14	115 25	POSE P P A T MUIST	
ROCK PROPERTIES METAMORPHIC: INTEMLAYERED TRANSITION BETWEEN QUARTZITE AND TACTITE. NODERATELY TO STRONGLY ALTERED METASEDIMEN WITH REPLACEMENT PYRITE. CHALCOPRITE AND MAGNETITE A CHALCOPRITE TO MEDIUM GRAINED.	PCT (+)6 IN.SIZE	34.1	SMAPE OF FRLCTIONS BETWEEN SCREEN SIZES	N AI		ANGLE/REPOSE 1 IN DROP DEGREES AT 1.5 PCT HOIST	30
100 100	MOISTURE PCT	1.	FR.CT10		CHANGE IN.SIZE	-	
IDENTIFICATION LK SAMPLE NO LK-3	DATA UNIT MOI: PCF PCT		HAPE OF		POT VOL CHANGE (-)0.056 IN.S	(-)0.75 IN.SIZE SPECIF GRAVITY	3.21
KEY IDENI 13 LK SAMPL LK-3	MUCK D ORY U	105	ÿ.		ă÷ o	ĵ. w. o	•••

1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	PCT (-) NO200	2.8
1	NOSO NO100 NO200	7.0
SCHID	NO 100	
SHORE NON SCHALDT	NO50	0.0
SHORE .		
700 PCT 70 70 60 60	RENS	5 1.2
COMPR SIGNIH KPSI EST IS IS IEST SPECIMEN BROKE ALONG STEEP INCLINE JOINTS DURING PREPARATION.	61N. 3fN. 21N. 11N. 1/21M. NO4 NOB NO16 NO30	9 1.6
	#E16MT 81	.2 1.6
200 V V V V V V V V V V V V V V V V V V	ENT BY 1	19.4 13.4 13.4 9.5 . 7.2
17 17 10 10	PER (13.4 9.
CTITE ST REPLACE RITE AN CATES F	In 21N	13.4
METAMORPHIC: TACTITE STRON ALTERED CALCAREOUS META- SEDIMENTS. WITH REPLACEMEN PYRITE. CHALCOPYRITE AND MAGNETITE AND A MIGH PER- CENTAGE OF SILICATES. FINE VERY FINE GMAINED.	6 IN. 3	19.4
ROCK PROMETANOR ALTERED SEDIMENTE PYRITE CENTAGE VERY FIN		. 1.16
	MOISTURE PCT(+)6 PCT IN.SIZE	7.10
EV IDENTIFICATION 14 LK SAMPLE NO LK-4	MUCK DATA ORY UNIT WT PCE	76.
> 4	503	

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES. A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

7.2

19.4 13.4 13.4 9.5

27.7

TOUGHNESS	SIZE(-). ANGLE INTER FRICTION DEGREES AT
PLASTIC LIMITS.SIZE(-) IN. S. S. S. S. S. S. S. S. S. S. S. S. S.	BULK BENSITY PCF AT IST PCT, MOIST
IZE(-) IN.C. PLASTICITY INDEX PCT	INAPPARENT BULK COMESION DENSITY PSF AT PCF AT ST PCI NOIST PCT,N
TERBERG LIHITSS SHRINKAGE LIMIT PČT	LE/SLIDE EL PLATE REES AT PCT HOI
PLASTIC LIMIT PCT	ANGLE/KEPOSE ANG ANGLE/KEPOSE ANG 10 IN UKOP STE DEGREES AT DEG
IN-SIZE LIQUID LIMITS PCT	IN.SIZE ************************************
POT VOL CHANGE (-) IN-SIZ	(-) IN.SI. SPECIF GRAVITY

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1 ,	PCT (16.3			•	:	O ÎN. Iter At Hoist	
	W0200	į			• • • • • • • • • • • • • • • • • • • •	¥	E(-)2. SLE IN ICTION GREES PCT	35
SCHIOT SCHIOT	NO100	1.1			TOUGHESS	9.0	1	
		. 1.3		. 2	FLOW	~ [BULK DENSITY PCF AT ,	141
SHORE	W030	1.8	P=PLATY C=CUBIC	, Y	1	;	BULK BULK DENS FOF	
R EST	SCREENS.	. 3.3		, V		1	PARENI MESION PCT	235
COMPR STRWTH KPS1	DETWEEN S	10.3 7.	- R=ROUNDET		SIZE(-) 0.0 PLAST INDEX FCI	7.2.		
25 PCF	NT BY WEIGHT 1/21N. NO&	20.1	S-SUBANGULAR R-ROUNDED	, M ,	LIMITS. INKAGE IIT	13.9	(-)2.0 IN ANGLE/SLIDE : STEEL PLATE DEGREES AT .2 PCT HOIST	31
CLAT CLAT PCT •	PER CE	7 11.4	A=ANGULAR S	4 .,	ATJEKBE 	-	4. S12E	
PERTIES IG: INTER LAVERED IATITE AND MANTITE INTED MONALLY FL IEN HIGHY FULDED IRON OVER 60 PCT 9 PCT SI: ICA S P	31N. 21N.	1.4 6.7	t	, IA IA	PLASTIC LIMIT PCT	15.1	ANGLE/KEPOSE 10 IN UROP . DEGREES AT	35
ROCK PROPERTIES METAMORPHIC: INTER LAYERED BANDS HENATITE AND NAKTITE HIGHLY JOINTED NORMLLY FLI LYING, OFTEN HIGHLY FULDED NATURAL IRON OVER 60 PCT MOISTURE 9 PCT. SI: ICA 5 PC	61M. 31	7.6	SHAPE OF FRACTIONS BETWEEN-SCREEN SIZES	₹ .	LIQUID LIMITS PCT.		AN AN DEC	
ROCK PROP HETAMORPH BANDS HEP HIGHY JG LYING OF NATURAL I	PCT(+)6.	7,2	IS BETWEEN		•	17.6	ANGLE/REPOSE 1 IN DROP DEGREES AT	37
44108	 MÕISTURE PCT	7.2	FRACTION	÷	CHANGE TINESIZE		IN.SIZE ************************************	
IS MATHER B SAMPLE NO HB-1	11. 11.	128 7	SHAPE OF		POT VOL CHANGE (+)0.056 IN.S.	•	(=10.75 E SPECIF GRAVITY	4.34

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	PCT (-) NO200	50.9	-SPHEROID				i i	
NA STOCK	NO 1 00 NO 2 00	7.7	A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID		TOUGHNESS INDEX	0.17	SIZE(-)2.0 I ANGLE INTER FRICTION DEGREES AT 9.3 PCT HOIST	o R
SHORE NON SCHILLT	9	10.2	: I=IRREGULA	ā	FLOU INDEX	•	BULK DENSITY PCF AT • 0 PCT, MOIST	75
SHORE NA	M030 N0	•	C=CUBIC	ă		0.4	• 1SI	
800 130 30	SCREENS.	4.0	O P ap laty	I 4	PLASTICITY (INDEX PCT		APPARENT COMESION PSF AT 9.3 PCT #	251
SIRNIH KPSI 11	BETWEEN NOS	*	R=ROUNDE	14	SIZE(-) 0.0 · PLASI INDEX PCI	6.7		
Per Port	ER CENT BY WEIGHT BETWEEN IN. 1/21N. NO4 . NO6	13.4	S=Subangular	1	ERG LIMITSS SHRINKAGE LIMIT FCI	22.7	SIZE(-)2.0 IN ANGLE/SLIDE STEEL PLATE DEGMEES AT 8.4 PCT MOIST	•
SEANS MICA FINE LY COARSE.	21N. 11N.	0 7.6 17.0		PE PE	PLASTIC. SHRINKAGE . PL PLASTIC. SHRINKAGE . PL LIMIT LIMIT LIMIT PCT FCT PC	23•3	**************************************	
AY TZ SE•	61N. 3IN. 21N. 1	0.0	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES		•			37
ROCK PROPERTIES METAMORPHICS GR. OCCASIONAL OUAR VARIES FROM DEN GRAINED TO EXTA	PCT (+)6 IN-S12E	0.0	NS BETWEEN		LIGUID LIMITS PCT	24.0	ANGLE/REPOSE 1 IN DROP DEGREES AT 8 PCT MOIST	39
IDENTIFICATION BUEEN LANE SAMPLE NO BL-1	MOISTURE PCT	0.	DF FRACTION		POT VOL CHANGE (-)0.056 IN.SIZE		IN.512E	
	MUCK DATA DRY UNIT WT PCF	108	SHAPE		POT VOL (-) (-) 0.056	•	(-)0.75 Specif Gravity	2.57
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		PCT (=)		SP=SPHEROID				O IN. ITER I A T HOIST	
101	4	NO100 NO206	9°0	S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED		TOUGHNESS INDEX	0.28	SIZE(+)2.0 ANGLE INTER FRICTION DEGREES AT 4.8 PCT MOI	56
SHORE NOH SCHMIDT	\$	NOSO NO	1.1 3.5	IC I=IRREGULA	∢	FLOW	5.0	BULK BENSITY PCF AT PCT WOIST	4
ROO SHORE	76	SCREENS	1.3	PLATY C=CUB	< <		-	APPARENT COHESION PSF AT PCT NOIST	ş
COMPR STRNTH KPSI	•	BETWEEN SCRI	4.4 2.7	R=ROUNDED Ps	PI PI	IZE(-) 0.1651N PLASTICITY INDEX PCI	1.40		
DRY FCT	171	PER CENT BY WEIGHT IIN. 1/2IN. NO4	15.5	=SUBANGUL AR	a Id	RG LINITSS SHRINKAGE LINIT PCT	15.18	SIZE(-)2.0 IN ANGLE/SLIDE STEEL PLATE DEGREES AT 6.3 PCT MOIST	56
ME FINE TED. PCT			33.6 20.9	A=ANGULAR S	Id	STIC .	15.50	AL SIZE E ST 6	
ROCK PROPERTIES SEDIMENTARY: SANDSTONE FII GRAINED: WELL COMPACTED: LIGHT BROWN OVER SO PCT		ein. Jin. 2in.	0.0	SCREEN SIZES				•	62
ROCK PROPERTIES SEDIMENTARY: SA GRAINED, WELL C LIGHT BROWN OVE		PCT (+) 6 In.S12E	0 • 0	FRACTIONS GETWEEN SCREEN		E LIGUID PCT	16.90	ANGLE/REPOSE 1 IN DrOP DEGREES AT	35
IDENTIFICATION 5-1 SAMPLE NO		A MOISTURE PCT	5.4	96		POT VOL CHANGE (-)0.065 IN.SIZE		IN.S12E	
17 5-1 SAMPLE	Ä	MUCK DATA DRY UNIT WI PCF	83	SHAPE		POT VOL (-) 0.065	•	(-)0.75 SPECIF GRAVITY	2.73

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		PCT (-) NO200	10.7	F=SPHEROID				O IN. ITER AT MOIST	
Seeres	4	M0108 W0200	3.0	S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SF=SPHEROID		TOUGHNESS	0.78	SIZE(+)2. ANCLE IN FRICTION DEGREES	;
SHORE MOH SCHMIDT	W.		1.2 2.5	IC 1=IRREGU	∢	FLOV INDEX	06.90	BULK BULK PCF AT •0 PCT NOIST	92.8
	19	**************************************	1.4 1	8n2=2 A	<		•	HOIST 0	
PCT	8	N SCREENS	2.6	ED P#PLAT	4	PLASTICITY FI INDEX	•	APPARENT COMESION PSF AT 2.8 PCT I	•
COMPR STRNTH KPSI	91	IT BETWEEN	4.3	R R=ROUND	Ĭ.	.17()	5.37	IN	
084 61 67	171	CENT BY WEIGH 1/2IN. NOA	22.6 15.4	R S=SUBANGULA	I d	RBERG LIMITS. SMRINKAGE LIMIT PCI	17.58	SIZE(-)2.0 IN ANGLE/SLIDE STEL PLATE DEGREES AT 2.6 PCT NOIST	62
ROCK PROPERTIES SEDINENTARY: SANDSTONE FINE GRAINED: WELL COMPACTED: UIGHT BROWN: GVER 50 PCT		**************************************	1.5 0.9 33.1 2	EN SIZES A=ANGULAR	14 14 1 15 14 15 15 15 15 15 15 15 15 15 15 15 15 15	PLASTIC SMRINKAGE PI PLASTIC SMRINKAGE PI LIMIT LIMIT PCI PCI	17.63	ANGLE/KEPOSE 10 IN DROP DEGREES AT 2.6 PCT MOIST	31
ROCK PROPERTIES SEDINENTARY: SA GRAINED: WELL C LIGHT BROWN: CV		PC7(+)6	0.0	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	ā	LIOUID LIMITS PCT	23.0	ANGLE/REPOSE 1 IN DROP DEGREES AT	35
10ENTIFICATION 7-2 SAMPLE NO		HOISTURE PCT	0.4	OF FRACTION		POT VOL CHANGE (+)0.056 IN.SIZE		IN. S12E	
18 7-2 18 7-2 SAMPLE 7-2		MUCK DATA DRY UNIT #T PCF	06	SHAPE		POT VOL (-) 0.056	•	(-)' 75 SPECIF GRAVITY	2.63

		PCT (-) NO200	0
	4	FER CEPT BY WEIGHT BETWEEN SCREENS	6.
SHORE WON SCHWIDT	Ş	950	1-1
HORE	PAPALLEL 41-55. Norhal 41-54.	030 N	•
700 PCT 51	2;2;	ENS	3.5 2.0
	MAJOR BEDS 22 TO 29. MINOR BEDS 5 TO 17.	EEN SCRE	3.5
COMPR STRNTH KPSI	4 MAJOR BEDS 22 TO 29. 22 MINOR BEDS 15 TO 17.	MT BETW	5.1
9 ± 9	152	BY WEIG	14.4 14.9 16.4 5.7
20 4	¥ .	ER CE:"	1.4.9
SEDIMENTARY: SMALE. MASSIVE TO SHINLY LAMINATED. INTERBEDDED SILISTONE AND SMALE. WITH	MINOR SANDSIONE AND LINESIONE LAYERS. GRAIN SIZE FINE TO COARSE. QUANTZ 24 TO 33 PCT.	21N. 1	
ES SHALE. TED. IN SHALE.	NE AND SIZE F 2 24 TO	6IN. 3IF. ZIN.	12.6 11.3
ROCK PROPERTIES SEDIMENTARY: SHI THINLY LANINATE!	SANDS TO GRAIN G. GUART		77
SEDIME	MINOR LAYERS COARSE	PCT (+)6 In.S12E	7.8
1CAT 10N NO		MOISTURE PCT	::
19 11-3 SAMPLE NO	11-3	MUCK DATA DRY UNIT	\$
KEY 19		•	

SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID

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IN FLOW TOUGMESS' INDEX	
FLOW	
EX.	
PLASTIC SHRINKAGE PLASTIC) PLASTIC SHRINKAGE PLASTIC EINIT END	
PLASTIC LIMIT PCI	
LIGUID LIMITS PCT	
OL CHANGE IN.SI.	
P07 (-)	

SIZE(-) IN- AMGLE INTER FFICTION DEGREES AT PCT MOIST
INAPPARENT BULK . COHESION DENSITY. PS5 AT PCF AT . PCT MOIST
IIZE(-) ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOI
ANGLE/REPOSE 10 IN UROP DEGREES AT
IN.SIZE ************************************
(-) IN.S SPECIF GRAVITY

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38.0

PCT (-) N0200 1.3			IN. NTER N N N N N N N N N N N N N N N N N N N
NA NA NA		TOUGHNESS INDEX	SIZE(*) ANGLE INTER FRICTION DEGREES AT PCT HOI
SHORE HON SCHMIDT SHORE HON SCHMIDT NA NA NA NA NA NA NA NA NA NA NA NA NA N	•	FLOS	BULK DENSITY, PCF AT MOIST
PARALLEL 41-55. NORMAL 41-55. NO30 NG NO30 NG LATY C=CUBIC 1			MOIST
REENS.		-) IN PLASTICITY INDEX PCI	APPARENT COHESION PSF AT PCT
SEDOED WIT STRNTH PCT SHORE WON SCHNIOT LAVERS 166 4 MAJOR BEDS 90 PARALLEL LAVERS 166 4 MAJOR BEDS 41-55. 22 TO 29. 22 TO 29. 22 TO 29. 24 TO 29. 25 TO 29. 26 MINOR BEDS 41-54. 19.3 15.7 12.7 3.4 2.5 1.2 0.6 0.2 0.2 1.3 A=ANGULAR S=SUBANGULAR R=ROUNDED PAPLATY C=CUBIC I=IRREGULAR E=ELCNGATED SP=SPHEROID	Aq Aq		(-) IN ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOIST
DRY WT PCF 166 . 1/21N. NG 15.7 12.7	A9	ERBERG LIMITS, SHRINKAGE LIMIT PCI	512 6
is a final in the second of th	⋖	LIGUID LIMIT PCT PCT PLASTIC LIMITS PCT	MATERIAL ANGLE/HEPOSE 10 IN DROP DEGREE> AT PCT HOIST
ROCK PHOPERTIES SEDIMENTARY: SHALE, MASSIVE TO SEDIMENTARY: SHALE, MASSIVE TO THINLY LAMINATED. INTERBEDDED THINLY LAMINATED. INTERMEDED SANDSTONE AND LIMESTONE LAYERS SANDSTONE AND LIMESTONE LAYERS GRAIN SIZE FINE TO COARSE. GRAIN SIZE FINE. 33 PCT. B.S. 17.7 17.0 19.3 18. B.Z. 17.7 17.0 19.3 18.	¥d.	LIGUID LIMITS PCT	IGLE/REPOSE IN DROP GREES AT
EY IDENTIFICATION ROCK PHOPERTIES 20 11-4 20 11-4 SAMPLE NO SANDSTONE AND SHALE WISTONE AND SHALE WISTONE AND LIMESTON SANDSTONE AND LIMESTONE AND LIM		POT VOL CHANGE (-)	(-) IN.SIZE AN SPECIF IN GRAVITY DE

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	PCT (-) NO200 7.9	P=SPHER010		O IN.	,
• • • • • • • • • • • • • • • • • • • •	NO100 NO200	E=ELONGATED S	TOUGHNESS INDEX 0.05	SIZE(~)2.0 ANGLE INTER FRICTION DEGREES AT 7 PCT HOI	30
SHORE MON SCHMIDT	SCREENS	A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=1RREGULAR E=ELONGATED SP=SPHEROID PI PI PI I I AI A I	PLASTIC SHRINKAGE PLASTICITY FLOW T LIMIT LIMIT INDEX INDEX INDEX I PCT PCT PCT A.0.2 4.0	BULK DENSITY PCF AT PCT MOIST	4
	. NO30	ATY C=CUB		. Ts	•
COMPR HOD STRNTH PCT KPSI EST		NUNDED P=PL/	(-) 0.1851N. -PLASTICITY INDEX PCI 0.2	APPARENT COHESION PSF AT PCT NOI	E.
DRY COMP WI STRN PCF KPSI	9.4	ANGULAR R=RO PI I	RG LIMITSSIZE(SHRINKAGE LIMIT PCT 9.6	(-)2.0 IN ANGLE/SLIDE STEEL PLATE DEGREES AT .4 PCT MOIST	31
	PER CENT BY (11N. 1/21N.) 18.0 2	GULAR S=SUB	ATTERBERG LI SHRIN LIMIT PCT 9.6	1 SIZE	
IMESTONE LIGH IMESTONE LIGH I FINE GRAINED DULES: TRACES AY PARTINGS	6IN. 3IN. 2IN. 11N. 1/2IN. NO. 0.0 3.0 25.0 18.0 22.1		PLASTIC - LIMIT PCT 12.3	ANGLE/REPOSE 10 IN UROP DEGREES AT 5.4 PCT MOIST	æ
ROCK PROPERTIES SEDIMENTARY: LIMESTONE LIGHT TO MEDIUM GRAY FINE GRAINED SOME CHERT NODULES: TRACES I OCCASIONAL CLAY PARTINGS	(+)6 SIZE	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	LIGUID LIMITS PCT 12.5	ANGLE/REPUSE 1 IN DROP DEGREES AT	38
ICATION NO	HOISTURE PCT PCT IN.	OF FRACTIONS	POT VOL CHANGE (-)0.065 IN.SIZE 0	IN.SIZE	m
ZI LAWPENCE SAMPLE NO LAW-2	MUCK DATA DRY UNIT WT PCF 92	SHAPE	POT VOL ((-) 0.065	(-)0.75 SPECIF GRAVITY	2.83

	PCT (-) NO200	6.6	*SPHEROID			IN.	
TÜÜ.	NO30 NO50 NO100 NO200	1 · 1	S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID	TOUGHNESS	0.41	SIZE(-)2.0 I ANGLE INTER FRICTION DEGREES AT 7 PCT HOIST	32
SHORE HOH SCHMIDI	NOSO NO	1.3	C I=IRREGULA I	•	2.9	BULK DENSITY' PCF AT PCT MOIST	X
SHORE 46		S	1 C=CUBIC		Ň	1015T	
800 PCT EST 100	SCREENS	5.0 3.5	D PEPLAT	• 1651R Sticit		APPARENT COMESION PSF AT PCT N	Z Z
COMPR STRNTH KPSI	BETWEEN NOS	7.4	R=ROUNDE	720	1.2		
087 VT 176	ER CENT BY WEIGHT IN. 1/2IN. NO4	20.2	S=SUBANGULAR PAI	ر بو ه	30.6	SIZE(-)2.0 IN ANGLE/SLIDE STEEL PLATE DEGREES AT 8.4 PCT HOIST	38
E LIGHT GRAINED• HACES TO NGS•	ZIN. 1IN.	25.9 19.6	A=ANGULAR : PAI PI	AITERBI STIC.	φ.	ST EA	
ITIES IS LIMESTONE LI KAY, FINE GRAI NODULES, THACE CLAY PARTINGS,	Z H M	0.0 4.3	EN SIZES		10.6	ANGLE/REPOSE 10 IN DROP DEGREES AT	9
ROCK PROPERTIES SEDIMENTARY: LIMESTONE LIGH 10 MEDIUM GHAY, FINE GRAINE SOME CHERT NODULES, THACES OCCASIONAL CLAY PARTINGS.		J	FRACTIONS BETWEEN SCREEN SIZES	LIQUID LIMITS PCT	11.8	REPOSE ROP S AT T MOIST	
8 8 ± 8 9	RE PCT(+)6 IN.SIZE	0.0	TIONS BE	ange In.size		ANGLE/REPOSE 1 IN DROP DEGREES AT 6.1 PCT MOIS	7
IDENTIFICATION LAWRENCE SAMPLE NO LAW-3	MOISTURE PCT	S• S	6			S IN.SIZE F TY	
KEY IDENTIFI 22 LAWRENCE SAMPLE N LAW-3	MUCK DATA DRY UNIT	6	SHAPE	PO. VOL. (~)	°	(-)0.75 SPECIF GRAVITY	2.80

•	PCT (-) NO200 14.3	SP#SPHEROIO		0 IN• 17ER 1 1 AT HOIST	
•••	NG30 NOS0 NO100 NO200	A*ANGULAR S#SUBANGULAR R#ROUNDED P#PLATY C#CUBIC 1#IRREGULAR E#ELONGATED SP#SPHEROID	TOUGHNESS INDEX 0.05	SIZE(-)2.0 ANGLE INTER FRICTION DEGREES AT 8.8 PCT MOI	58
SHORE MOH SCHMIOT		I=IRREGULAR A	×	BULK BULK DENSITY PCF AT POIST	4
SHORE	•	ATY C=CUBIC PA PA		MOIST	42
R ROD TH PCT EST 103	CENT BY WEIGHT BETWEEN SCREENS 1/21N. NO4 NO8 NO16 18.3 17.0 7.3 5.1 3.4	UNOED P=PLA	*ATTERBERG LIMITSSIZE(-) 0.056IN Shrinkage .plasticity Limit pct pct 13.5 0.2	APPARENT COMESION PSF AT PCT M	Ź
COMPR STRNTH KPSI 13	WEIGHT BETWE . NO4 NO 17.0 7.3	46ULAR R=R0	MITS.SIZE(KAGE	(-)2.0 IN ANGLE/SLIDE STEEL PLATE DEGREES AT	37
DRY WI PCF	2 CENT BY W W. 1/21N. 18.3 17	LAR S≖SUBAN	ITERBERG LIM SHRINH LIMIT PCT 13.5	S12E	
ROCK PROPERTIES SEDIMENTARY: LIMESTONE LIGHT TO MEDIUM GRAY FINE GHAINED. SOME CHERT NODULES: THACES TO OCCASIONAL CLAY PARTINGS.	6IN. 3IN. 2IN. 1IN. 0.0 5.0 18.3 18		PLASTIC PLIMIT PCT 20.0	ANGLE/MEPOSE 10 IN UROP DEGREES AT 8.9 PCT MOIST	ž
ROCK PROPERTIES SEDIMENTARY: LI TO MEDIUM GRAY SOME CHERT NODU OCCASIONAL CLAY	PCT(+)6 IN.S12E 0.0	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	12E LIGUID LIMITS PCI 20.2	ANGLE/REPOSE 1 IN DROP DEGREES AT 8.9 PCT HOIST	2*
REY IDENTIFICATION 23 LAWRENCE SAMPLE NO LAW-4	MUCK DATA DRY UNIT MOISTURE WT PCF PCT 80 7.9	SHAPE OF FRACT	POT VOL CHANGE (-)0.056 IN.SIZE 0	(-)0.75 IN.SIZE SPECIF GRAVITY	2.73

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		•	•	S#SUBAMGULAR R#ROUNDED P#PLATY C#CUBIC I*IRREGULAR E#ELONGATED SP#SPHEROID		•		E.O IN. INTER ON S AT T HOIST	
101	•	NO30 NO50 NO100 NO200	v.	REELONGATE			9.54	SIZE(-)2.0 ANGLE INTER FRICTION DEGREES AT 3.5 PCT MOI	38
DNESS	*	NO.	5.0	RREGUL AF	v			117 AT PCT, H01ST	9
SHORE MON SCHMIDT	ž)50N	2.	1=1 D18	v	FLOW INDEX	2.00	BULK BENS PCF 0.0	
	ž	•	0	NTY C=CU	v			RENT SION AT PCT MOIST	9 5
Red PCT EST	8	SCREENS. NO 16	6.2)EO P#PL/	4) 0.056IN.PLASTICITY INDEX PCT	.21	APPA COHE PSF	•
COMPR STRNTH KPSI	98	SETWEEN NOS	8.2	R REROUNG	Id	SIZE(-)	÷.	INIDE ATE ATE ATI	
SE SE	166	CENT BY WEIGHT	24.0	:=Subameula	ī	ERG LIMITS. Shrinkage Limit PCT	15.46	SIZE(-)2.0 ANGLE/SLIDE STEEL PLATE DEGREES AT 2.5 PCT HOI	30
ES LIMESTONE, GRAV HORIZONIAL A IN. TO 1 FOOT.		61N. 3IN. 2IN. 1IN. 1.	0.0 0.0 14.5 28.0	A=ANGULAR	1d 3d	PLASTIC. SHRINKAGE PRINITS.SIZE(=) PLASTIC. SHRINKAGE PRINIT POT	15.69	ANGLE/MEPOSE 10 IN UROP DEGREES AT 2.5 PCT MOIST	35
ROCK PROPERTIES SEDIMENTARY: LIMESTOWE. FINE GRAINED: HORIZONTAL	Join Stating	PCT(+)6IN.SIZE 6IN.	0.0	IS BETWEEN SCRE		E LIGUID PCT	16.90	ANGLE/REPOSE 1 IN DROP DEGREES AT	36
IDENTIFICATION MILWAUKEE	SAMPLE NO MIL-1	DATA Unit Moisture PCF PCT	89 5.5	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES		POT VOL CHANGE (-)0.056 IN.SIZE	•	(-)0.75 IN.SIZE **. SPECIF ANGRAVITY DE	2.89
KEY 1		NUCK DRY ET							

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RODHARDNESS PCT SHORE MOH SCHMIDT EST	BS NA NA NA	SCREENS PCT (-) NO16 NO30 NO50 NO100 NO200 NO200	6.8 4.9 2.7 3.2 7.6 8.6	A=ANGMAR S*SUBANGMAR R=ROUMDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID	S S) IN FLOW TOUGHNESS INDEX INDEX PCT	APPARENT BULK ANGLE INTER COHESION DENSITY FRICTION PSF AT PCF AT DEGREES AT PCT MOIST PCT MOIST
COMPR STRNTH KPSI	9 6	BETVEEN NOB	11.5 6.	IR R=ROUMDED	r d	PLAST PLAST INDEX PCT	N IS
DRV WIT PCF	166	CENT BY WEIGH 1/21N. NOV	24.7 22.8	R S#SUBANGUL!	4	RBERG LIMITS. SHRINKAGE LIMIT PCT	SIZE(-) ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOI
ROCK PROPERTIES SEDIMENTARY: LIMESTONE, GRAY, FINE GRAINED, HORIZONTAL JOINT SPACING 6 IN, TO 1 FOUT,		C	0.0 0.0 9.2 Z		PE PI	**************************************	ANGLE/REPOSE 10 IN DROP DEGREES AT PCI MOIST
ROCK PROPE SEDIMENTARY FINE GRAIN SPACING 6		PCT(+)6 IN-SIZE	o •	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES		321	ANGLE/REPOSE 1 IN DROP DEGREES AT PCT MOIS
IDENTIFICATION MILWAUKEE SAMPLE NO	MIL-2	CK DATA RY UNIT MOISTURE F PCF PCT	89 6.1	SHAPE OF FRACI		POT VOL CHANGE	(-) IN.SIZE SPECIF GRAVITY

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MUCK DATA DRY UNIT WT PCF

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	PCT (-) NO200	25.7	SPHERO1D				ž.	
***101	SCREENS NO30 NO50 NO100 NO200	0	A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID		TOUGHNESS INDEX	0.52	SIZE(-)2.0 I ANGLE INTER FRICTION DEGREES AT 3.6 PCT HUIST	38
SHORE NOH SCHMIDT	NOSO NO	15.4	C I=IRREGULAR	∢	•	9	BULK DENSITY: PCF AT	4.16
	NO30	2.7 1.8	ĭY C≖CU81	∢		•	10157	
# PCT 8	EN SCREENS	3°*	10ED P=PLA1	< <) 0.056IN PLASTICITY INDEX PCT	3.14	APPARENT COMESION PSF AT 3.6 PCT I	216
COMPR STRNTH KPSI 10	EIGHT BETWEEN : NO4 NOB	•	LAR R=ROU!	∢	TTERBERG LIMITSSIZE(-) SHRIMKAGE PL LIMIT IN PCT PCT	ř.	IN IDE ATE HOIST	
084 41 905	ER CENT BY WEIGHT IN. 1/2IN. NO4	12.0 12.6	S=SUBANGU	∢	BERG LIMIT SHRINKAG LIMIT PCT	15.17	SIZE(-)2.0 ANGLE/SLIDE STEEL PLATE DEGREES AT 3.6 PCT MOIS	27
E MEDIUM TO RED. LY	IN. IIN.	5.7 12	A=ANGULAR	id Id	PLASTIC LIMIT PC1	17.06	ST m K	
TIES SANDSTON SHI BROWN ROUS. POOR	61N. 3IN. ZIN. 1	7.6 7.5	SEN 512ES	i a	PLA LIN	11	ANGLE/KEPOS ANGLE/KEPOS 10 IN UROP DEGREES AT 3.6 PCT MOI	35
ROCK PROPERTIES SEDIMENTARY: SANDSTONE MEDIGRAINED. LIGHT BROWN TO RED MASSIVE. POROUS. POORLY CEMENTED.	PCT(+)6 ****		SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	-	LIOUID LIMITS PCT	21.20	ANGLE/REPOSE 1 IN OROP DEGREES AT	
	MOISTURE PCT PCT IN•	•	RACTIONS B		iange In.size		IN.SIZE **** ANGLE IN OEGRE 3.6 P	37
IDENTIFICATION LAYOUT Sample no Lay-1	DATA UNIT PCF	105 4.1	SHAPE OF F		POT VOL CHANGE (-)0.056 IN.S	0	(-)0.75 IN.SPECIF GRAVITY	2.66
78 28 4 28 4	MUCK DRY #T							

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	PCT (~) NO200	90.	F=SPHERQID		O IN. ITER I A T Hoist	; •
HHIDT NA	NO100 NO200	SCREENED BEFORE DRYING	R E=ELONGATED SP=SPHERQID A	TOUGHNESS INDEX 1.88	SIZE(+)2. ANGLE IN FRICTION DEGREES 7.5 · PCT	- v e
SHORE MOH SCHNIDI	N050	LINE	C=CUBIC I=IRREGULAR	FLOW INDEX 7.00	BULK DENSITY PCF AT 0.0 PCT MOIST	8 6
ROD PCT EST 70	N SCREENS	TH C117).	0ED P=PLATY C=C S S	-) 0.056IN PLASTICITY HNDEX PCT 13.19	APPARENT COHESION PSF AT 7.5 PCI, MOIST	340
DRY COMPR WI STRNTH PCF KPSI 142 2	I/ZIN. NO4 NO8	AFTER WASHING	S=SUBANGULAR R=ROUNDED P=PLATY AI SI S S	LIMITSSIZE(- INKAGE IT	I(-)2.0 IM ANGLE/SLIDE STEEL PLATE DEGREES AT	30
SILTSTONE FINE HORE THAN 33 PCT CLAY 10 IS PCT MICA*	ZIN. 11N. 1/2	23.0 EU (ASTH	A=ANGULAR PI PI	PLASTIC LIMIT PCT 23.61	ANGLE/METERIAL SIZE(-)2.0 ANGLE/MEPOSE ANGLE/ 10 IN UROP STEEL DEGREES AT DEGREE 7.7 PCI MOIST 7.7 PC	30
ROCK PROPERTIES SEDIMENTARY= SILTSTOME. F GRAINED. GRAY. MORE THAN 3 PCT OUARTZ. 30 PCT CLAY. I PCT FELUSPAR. 15 PCT MICA. CHLORITE AND GYPSUM.	(+)6	19. ER LINE, DRY	FRACTIONS BETWEEN SCREEN SIZES	LIGUID LIMITS PCT 36.80	ANGLE/REPOSE ANGLE/REPOSE 10 1 In DROP 10 DEGPEES AT DEG	•
KEY IDENTIFICATION 27 NAVAJO SAMPLE NO NAV-1	MUCK DATA DAY UNIT MOISTURE PO	REEN ANALYSIS:	SHAPE OF FRACTIONS	POT VOL CHANGE (-)0.056 IN.SIZE 1.3	(-)0.75 IN.SIZE **** SPECIF GRAVITY DEGR	3,13 30

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' ',	t ,	PCT (-) NO200	29•1 NG	P=SPHERO1D	1		IN. TER AT HOIST
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SCHHIDT	Ž ,		10.0 SCREENED	EGULAR E	1	100 100 100 100	11TV AT #01ST
HO	\$	950#	12.7 1 ER [TNE.	IC I=IRR		FLOW	BULK DENSITY PCF AT
SHORE	4 , .		23.2 13 17) • 104E	17 C=CUB	4		11 NO 1 HOIST
FC1 00 11 11 11 11 11 11 11 11 11 11 11 11	5 , :	SCREENS NO16	11.6 2: STM C117	EO P#PLA	. 	PLASTICITY INDEX PCT	APPARENT COHESION PSF AT
COMPR STRNTH KPS1	LESS THAN 1	T BETWEEN NOS	2.5 2.3 11.8 23.2 AFTER WASHING (ASTM CLIT).	R R=ROUND	Ĭď		106 106 ATE A1 H01ST
94.74 24.74	i in	NT BY WEIGHT 1/21N* NO4	2.5 . AFTER W	SUBANGULA	*	TERBERG LIMITS. SMRIMKAGE LIMIT PCT	MGLE/SL MGLE/SL TEEL PL EGREES PCT
1	, · · .	8 5 8	1.3	GULAR S	◀	. .	11AL SIZE(
SEDIMENTARY SANDSTONE GRAY MEDIUM TRAYES MASSIVE.	SUBROUNDED. OUARIZ. POORLY	NIG	0.0 0.0	-	AI AI	PLASTIC LIMIT PCT	ANGLE/KEPOSE 10 IN UROP DEGREES AT PCI MOIST
SEDIMENIARY: SAMOSIONE G SEDIMENIARY: SAMOSIONE G MEDIUM GRAIMED: MASSIVE: FAID POROUS: GHAI	TO SUBROUNDED.	618. 31	00	CREEN ANALYSIS: UPPER LIME. DRY SCHEENE SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	,	Liouio Limits Pct	ANGLE/REPOSE 1 IN DROP DEGREES AT PCT MOIST
SEDINE:	ANGULAR TO PRIMARILY CEMENTED.	PCT (+)6 IN-SIZE	•	X	1		ANGLE/REPO A IN DROP DEGREES AT
CATION	9	MOISTURE PCT	; & .	SCREEN ANALYSIS:	1	POT VOL CHANGE (-) IN.SIZE	IN.SIZE F
IDENTIFICATION NAVAJO	SAMPLE NO NAV-2	MUCK DATA DRY UNIT WT PCF		SCREEN I	,	POT VO	(*) SPECIF GRAVITY
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KEY 29	IDENTIFICA WESTERN NUCLEAR	IDENTIFICATION WESTERN NUCLEAR	ROCK PR SEDIMEN GRAINED	ROCK PROPERTIES SEDIMENTARY: SANDSTONE COARSE GRAINED: POORLY CONSOLIDATED:	S ANDSTON Y CONSU	WE COAR	: 0 •	DRY #T	COMPR		50	SHORE	HARDI	SHORE WOH SCHMIDT	101		1 4
ŧ	SAMPLE WNG-1	O	ARKOSIC THIN SE	ARKOSIC. WITH MINOR LATERS THIN SEAMED SILTSTONE.	H MINOR LA S <u>i</u> ltstone•	E. E.	, ' 5	2 2	LESS THÂN	:		* \$	₹'	T .	; !	t 1	· · · · · · · · · · · · · · · · · · ·
1	1 %		*	!	٥.		t*		t	v	1	1	•	1	<i>4</i> ,	ŧ	ı
302	MUCK DATA DRY UNIT WT PCF	MOISTURE	PCT (+)6 IN-SIZE	_	31N.	6IN. 3IN. 2IN. 1	ਠ ਛੜ	ENT BY WEIGHT	HT BETWEEN	EN SCREENS.	•	- F030	- WOSO	WO108		NO200	. PCT (+)
	B 2	10.5	0.0	• •	9.9	0.0 15.7	1.0	2.6	9.5	12.0	17.0	16.0		14.0	6.1	ŧ *	24.9
	SCREEN	SCREEN ANALYSISE	UPPER LINE.	E. DRY	DRY SCREENED	EU (ASFI	и с136)•		AFTER WASHING	(ASTH C117).	117.	LOWER	LOWER LINE. S	SCREENEC	SCREENED BEFORE DRYING	E ORYIN	9
	SHAPE	OF FRACTIO	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	SCREEN	SIŽES	A=ANG	J. AR	SUBANGUL	S=SUBANGULAR R=ROUNDED P=PLAIY C=CUBIC I=IRREGULAR E=ELONGATED	NOED P.	PLATY	C=CUB16	. 1=1RRI	EGULAR E	E=ELONG!	ATEO SA	SP=SPHERO1D
i	1		1	¥E	. A.	, VE	, , ,	! «	· «	· · «	•	⋖ १	, « .	•	3	ţ	•
i ,		POT VOL CHANGE (-)0.056 IN.SIZE			PLAST LIMIT PC;	STIC	11ERBER	TTERBERG CIMITS. SHRINKAGE LINIT PCT		e.e. LAST NDEX			FLOW	, 10c	TOUGHNESS	•	-
	, ,		24.90	06	ž	19.97		19.94	•	66.4	•		•	, .	. 99.0	i	:
		IN.SIZE	ANGLE/REPOSE 1 IN DROP DEGHEES AT	:	ANGLE/REPO 10 IN DROP DEGREES AT	ANGLE/REPOSE 10 IN UROP DEGREES AT 0.1 PCT MOIST	LSIZE	ゟヹぃ⊢	IN IDE ATE AT MOIST	APPARENT COHESION PSF AT	APPARENT COHESION PSF AT			SITY AT PCT MOIST	SIZE(-)2.0 ANGLE INT FRICTION DEGREES A 10.6 PCT H	-)2.0 I E INTER TIÓN EES AT PCT MQIST	. TSI
	2.71		34		33			32			•		92		27	•	

	PCT (-) NO200	20.1	.	>=SPHEROID				O IN. ITER AT HOIST	
: :		7.9	SCREENED BEFORE DRYING	E=ELONGATED SA		TOUGHNESS INDEX	0.13	SIZE(-)2.0 ANGLE INTER FRICTION DEGREES AT 9.0 PCT MOI	28
HOH SCHIOT	010N 050N	16.0 16.0	LOWER LINE. SCREENE	C=CUBIC I*IRREGULAR E=ELONGATED SP=SPHEROID	∢	FLOW TO	•••	BULK DENSITY PCF AT 0.0 PCT HOIST	98
RED PCT SHORE EST SHORE 3.0 NA	SCREENS	16.0			< 	S6INICITY	•	PARENT FESTON T AT PCT MOIST 0	•
COMPR STRNTH KPSI LESS THAN 1.	WEIGHT BETWEEN SON NO.	5.0 11.0	R WASHING (ASTN C117).	S=SUBANGULAR R=ROUNDED P=PLATY		_120	0.51	IN	
125 PG	CENT BY	2.0 4.0	STH C1361+ AFTER	A=ANGULAR S=SUBANG	∢ vı	•ATTERBERG LIMITS••SIZE(-) SHRIWKAGE LIMIT PCT	23.37	FERIAL SIZE(-)2.0 EPOSE ANGLE/SLIDE ROP STEEL PLATE AT DEGREES AT HOIST 9.0 PCT HOIS	0
ROCK PROPERTIES SEDIMENTARY: SANDSTONE COARSE GRAINED. POORLY CONSOLIDATED. ARKOSIC. WITH MINOR LAYERS OF THE SCHOOL SILTSTONE. VARYING CONCENTRATIONS OF CARBONIFENOUS MATERIAL REPLACED BY SILICA.	6	0.0 0.0 0.0 8.7 5.4 7.9	DRY SCREENED (AST		AE AE AE	PLASTIC LIMAT PCT	24.74	ANGLEZKI 10 IN DI 0 GGREES 9.0 PCT	31
ROCK PROPERTIES SEDIMENTARY: SAMDSTONE GRAINED, POORLY COMSOL ARKOSIC, WITH MINOR LA OF THIN SEAMED SILISTO VARYING CONCENTRATIONS CARBONIFEHOUS MATERIAL REPLACED BY SILICA.	PCT(+)6 ***IN-SIZE 6IN	00	ER LINE.	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	·	LIOUID LIMITS PCT	25.25	ANGLE/REPOSE 1 IN DROP DEGREES AT	32
10ENTIFICATION ESTERN NUCLEAR SAMPLE NO WNG-2	TA IT MOISTURE F PCT	8.3	EN ANALYSISE	PE OF FRACTIO		POT VOL CHANGE (-)0.056 IN.SIZE		(-)0.75 IN.SIZE **. SPECIF ANG GRAVITY DE(Ñ
KEY IOENTIF 30 MESTERN NUCLEAR SAMPLE MNG-2	MUCK DATA DRY UNIT	69	SCREEN	AHS	n 20	P04 (-)	•	SPE GRA	2.72

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	* PCT (-)	SP=SPHEROID		LBS IN.	
MA MA	12.8	A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID	TOUGHNESS INDEX 0.27	SIZE(-)0.185 ANGLE INTER FRICTION DEGREES AT 13.0 PCT MOIS	2
SHORE NON SCHMIOT	SCREENS	C I=IRREGULA	FLOW INDEX 5.6	BULK BENSITY PCF AT COIST	4 2
	SN030	ATY C=CUBI(4015T	
7 R0D IH PCT EST NN 1. 0-35	EN SCREENS B NOIG 5.1 7	NDED P=PLA	-) 0.185IN PLASTICITY INDEX PCT 1.56	APPARENT COMESION PSF AT PCT P	4
COMPR STRNTH KPSI KPSI	CENT BY WEIGHT BETWEEN 1/21N. NOA NOB 1:2 4.5 6.1 5	ULAR R=ROU Ai	TSS1ZE (~ GE	S IN LIDE LATE AT HOIST	
P. P. C. L. L. L. L. L. L. L. L. L. L. L. L. L.	ENT GY WE! 1/21N. P	? S=SUBANG	RBERG LINI SHRINKA FCT 13.94	SIZE(-)0.185 ANG.E/SLIDE STEEL PLATE DEGREES AT 12.5 PCT NOI	98
ROCK PROPERTIES SEDIMENTARY: SANDSTONE ARKOSIC IRREGULARLY BEDDED. LOOSELY CONSOLIDATED WITH LAYERS AND LENSES OF SILTY MUDSTONE.	6IN. 3IN, 2IN. 1IN. 1		PLASTIC SPRINKAGE PLINITSSIZE(-) PLASTIC SPRINKAGE PLINIT IN IN PCT PCT PCT PCT PCT PCT PCT PCT PCT PCT	ANGLE/KEPOSE 10 IN UROP DEGREES AT	33
ROCK PROPERTIES SEDIMENTARY: SA IRREGULARLY BED CONSOLIDATED WI LENSES OF SILTY	PCT(*)6 * IN-SIZE 6IN.	NS BETWEEN SCRE	LIGUID LIMITS PCT 17.75	ANGLE/REPOSE 1 IN DROP DEGREES AT 14.3 PCT HOIST	38
IDENTIFICATION SAN FERNAL'DO SAMPLE NO SF-1	MUCK DATA DRY UNIT MOISTURE WT PCF PCT 91 18.5	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES	POT VOL CHANGE (-)0.065 IN.SIZE 0	(-)0.185IN.SIZE G SPECIF GRAVITY	2.06
W W W					

	PCT (-) NO200 19.0	SP=5PHER010			10 IN. 1TER 4 AT HOIST	
•••	SCREENS	A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID	TOUGHESS		SIZE(+) IA ANGLE IN FRICTION DEGREES IS PCT	23
SS SCH	NOI 9.5 SCREEN	REGULAR			117 A1 PCT H01ST	_
14 TOT 14	NO50	I=1RR	FLOW	7.6	BULK DENSITY PCF AT PCT N	4
SHORE NON SCHALDT	NO36 1.5	C=CUBIC	, in the second	-	MOIST .	
. 5. EST	SCREENS NOI6 0.6 0.6 STH CLI7)	ED PEPLATY	51 51 0.0561N	: _	APPARENT COMESION PSF AT	\$
CONTR STEEL'TH RPSI	IT BETWEEN NOB S G	AR R=ROUND	S1ZE(-	1.4	IN 1DE ATE AT AI MOIST	
2 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	1/214. NO. 1/214. NO. 4. 34.6 4. 34.6	Suskameul I	SI ERG LIMITS SYRINKAGE	21.5	SIZE(-)1.0 ANGLE/SLIDE STEEL PLATE DEGREES AT 15.1 PCT NOT	æ
INTIES IVE SANDSTONE AND RICH SILTSTONE. WELL CONSOLIDATED. WELL SONTED.	24N. 11N. 8.6 14.	1	RY, PLASTIC LIMIT .	PC1 26.8	ANGLE/MEDOSE 10 IN DE. P DEGREE' "	36
ROCK PROPERTIES SEDIMENTARY: SANDSTONE SICTITE RICH SILTSTON POORLY TO WELL CONSOLI PCORLY TO WELL SONTED.	٠.٠	CREEN ANALYSIS: UPPER LIME, UNT SUNCEN. SHAPE OF FRACTIONS & TWEEN SCREEN SIZES	PE NE LIQUID	9cT 31.5	ANGLE/REPOSE 1 IN DROP DEGREES AT 15.1 PCT MOIST	99
Y IDENTIFICATION 2 SAN FERNANDO . SAMPLE NO SF-2		SCREEN ANALYSIS!	POT VOL CHANGE (-)0.056 IN.SIZE	•	(-)0.75 IN.SIZE SPECIF GPAVITY	3.02
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SIZE(-) IN.
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DEGREES AT
PCT MOIST

IN....APPARENT BULK

COMESION DENSITY

PSF AT PCF AT

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ANGLE/SLIDE STEEL PLATE DEGREES AT PCT MOIST

IN.SIZE ANGLE/REPOSE ANGLE/REPO

(-) I SPECIF GRAVITY

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·	PCT (-) NO200	29.6 ING	SP#SPMER010		
CHAIDT NA	NO100 NO200	5.2 28.9 0.3 1.3 2.7 5.4 6.3 12.5 5 6.4 3.3 12.5 7 6.4 3.3 12.5 7 6.4 6.3 12.5 7 6.4 6.4 7.3	.AR E=ELONGATED !		TOUGHNESS INDEX
SHORE MON SCHUIDT	•	5.4 6.3 HER LINE. SCRE	UBIC I=IRREGU	< <	FLOW INDEX IN
800 PCT SHOS EST SHOS	REENS	2.7	Paplaty CaC		-) IN PLASTICITY IMDEX PCT
COMPR Strnth KPSI 11	IT BETWEEN SC NOB	0.3 1.3 IASHING (ASTH	IR R=ROUNDED	< <	SIZE(-) PLASI IMDE) PCT
PCF PCF	ent by Weigh 1/2in. No4	2 26.9 4 3.3 36) • AFTER 1	S=SUBANGUL/	∢	ATTERBERG LIMITSSIZE(-) Shrinkage Limit PCT
ROCK PROPERTIES SEDIMENTARY: MUDSTONE, DARK GRAY, FINE GRAINED, MASSIVE,	61W. 3IN. ZIN. 11W. 1/ZIN. NO4 NO8 NO16 NO30 NO50	0.0 46.7 20.1 8.4 11.0 6.4 UPPER LINE. ORY SCREENED (ASTM C13	SHAPE OF FRACTIONS BETWEEN SCREEN SIZES A=ANGULAR S=SUBANGULAR R=ROUNDED P=PLATY C=CUBIC I=IRREGULAR E=ELONGATED SP=SPHEROID	Id Id Id 3d	DID PLASTIC LINIT PCT
ROCK PROCK P	PCT(+)6 IN.SIZE	0.0 46.7 UPPER LIN	NS BETWEEN	3	
IDENTIFICATION KERR-MGGEE . SAMPLE NO KM-1	HOISTURE PCT	81 9.4 SCRFN ANALYSIS:	OF FRACTIO		POT VOL CMANGE (-) IN.SIZE
KEY IDENTIFICA 33 KERR-MGGEE SAMPLE NO KM-1	MUCK DATA DRY UNIT WT POF	90 V	SHAPE) (°)

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MASTAR	C-3, C-4
MAST-3	C-5, C-6
NAST-4	0.7, C.8
CA-1	G-9, C-10
[]	C-11, C-12
	C-13, C-14
1.8-1	C-15, C-16
1.13-2	C-17, C-18
LK-5	C-19, C-20
7.K-6	C-21, C-22
Cis-1	C-23, C-24
LK-3	C-25, C-26
LK-4	C-27, C-28
I-ELN	C-29, C-30
Q11	C-31, C-32
6-1	C-33, C-34
7-2	C-35, C-36
11.3.	C-37, C-38
11-4	C-39, C-40
LAW-2	C-41, C-42
LAW-3	G-43, C-44
LAW-4	C-45, C-46
MIL-1	C-47, C-48
MIL-2	C-49, C-50
LAY-1	C-51, C-52
NAV-1	C-53, C-54
NV A - 5	G-55, G-56
WNG-1	G-57, C-58
WNG-2	C-59, C-60
SF-1	C-61, C-62
SF-Z	C-63, C-64
KM-1	C-65, C-66

Lithology: Igneous, granite, gray, medium to fine grained, moderately to slightly fractured and jointed, 10 to 20% quartz, 50 to 60% feldspar, balance dark minerals.

Uniaxial Compressive Strength: 18 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 167 PCF.

Ground Water: Minor, primarily from fault zones.

Hardness: NA 1-11-72.

TUNNEL DATA:

Size: 91 91 diameter. Grade: (+) 0.22%.

Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5 to 20 gpm. Power System: 4160/480V.

Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 70# rail.

Support System: 4'' ring and half sets, at 4', 3' and 2' centers in bad ground, 13'' wide x 10' - 16 gage plates secured by 4-1'' x 7' grouted bolts as required.

EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model. Weight: 67 tons.

Cutters: 25 Hughes Tool/Wirth Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 15-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB Cone.

Rotation: Head, 8 to 11 RPM.

Torque: 600 HP.

Thrust: 500 K lbs.

Muck System: Bucket from face, 22" belt conveyor to rear.

Power System: 3-200 HP electric motor driven hydraulic pumps driving hydraulic motors.

Guidance System: Laser.

MDN STUDY SYSTEM DATA SHEET T-M5 Ident. No. NAST-1 Sheet 1

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material Size-0.065": 0

Spec. Gravity, Material Size - 0.50": 2.69

ATTERBERG LIMITS, MATERIAL SIZE (-)0.185 IN.

Liquid Limit 14.50% Plasticity Index 0.50 % Plastic Limit 14.00% Toughness Index 0.16 Shrinkage Limit 13.50% Flow Index 3.0

MATERIAL SIZE (-)0.50 IN.

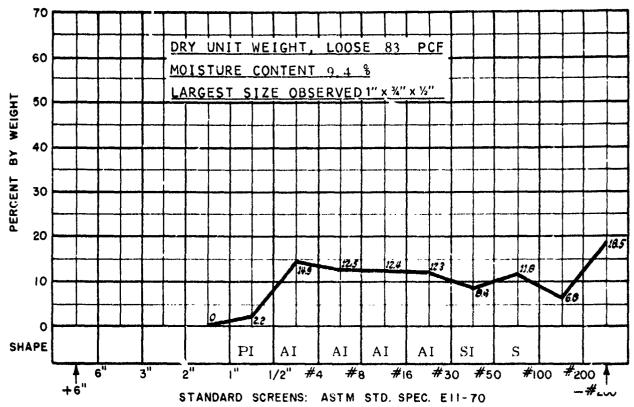
Angle/Repose 1 In. Drop @ 9.0% Moisture, 37° Angle Slide Steel Plate @ 9.0% Moisture, 41° Apparent Cohesion PSF

(a) % Moisture, NA

Bulk Density PCF

(a) % Moisture, NA

Angle/Repose 10 In. Drop @ 9.0% Moisture, 36° Angle Internal Friction @ 8.5% Moisture, 42°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, moderately to slightly fractured and jointed. Medium to fine grained. High strength. RQD (Est.) 90%. DUW; 167 PCF. Cround water: Minor. Hardness: NA.

System Class: TBM, Wirth Erkelenz, Hardrock, 9191 diam, 25 Hughes Tool/Wirth TCBI roller and cone cutters. RPM; 8-11, 600 HP Torque, 500 K# Thrust. Mucking: Buckets to belt. Haulage: Rail. Suprort: Steel ring and half sets,

roofplates and rock bolts.

MDN STUDY SYSTEM DATA SHEET MDN T-M5 Ident, No. NAST-1 Sheet 2

Lithology: Igneous, granite, gray, medium to fine grained, moderately to slightly fractured and jointed, 10% to 20% quartz, 50% to 60% feldspar, balance dark minerals.

Uniaxial Compressive Strength: 18 KPSI.

RQD: (Estimated) 90%.
Dry Unit Weight: 167 PCF.

Ground Water: Minor, primarily from fault zones.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 9'9" diameter. Grade: (+) 0.22%.

Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5 to 20 gpm. Power System: 4160/480V.

Haulage System: Muck, personnel, supplies by rail cars, 36" gage 70# rail.

Support System: 4" ring and half sets, at 4', 3' and -' centers in bad

ground (approximately 6501), 13'' wide x 10^{4} - 16 gage plates secured by

4-1" x 7' grouted bolts as required, (approximately 1200').

EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model, Weight 67 tons.

Cutters: 25 Hughes Tool/Wirth Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 15-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB cone.

Rotation: 8 to 11 RPM.

Torque: 600 HP Thrust: 500 K lbs

Muck Bystem: Bucket from face, 22" belt conveyor to rear.

Power System: 3-200 HP electric motor driven hydraulic pumps driving

hydraulic motors and cylinders.

Guidance System: Laser.

MDN STUDY SYSTEM DATA SHEET T-M5 Iden

Ident. No. NAST-2 Sheet 1

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material Size- 0.056": 0

Spec. Gravity, Material

Size -0.50'': 2.66

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 19.5 %
Plasticity Index 1.3 %

Plastic Limit 18.2 %, Toughness Index 0.28 Shrinkage Limit 17.9%

Flow Index 4.6

MATERIAL SIZE (-)1.0 IN.

Angle/Repose I In. Drop @ 8.7% Moisture, 38° Angle Slide Steel Plate @ 8.7% Moisture, 49°

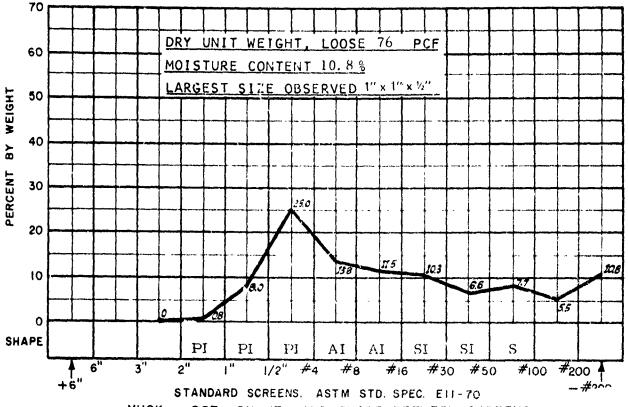
Apparent Cohesion PSF

(a) ", Moisture, NA

Bulk Density PCF

(a) ", Moisture, NA

Angle/Repose 10 In. Drop @ 8.7% Moisture, 38° Angle Internal Friction @ 8.5% Moisture, 31°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, medium to fine grained, moderately to slightly fractured and jointed. High strength. RQD: (Est.) 90%. DUW: 167 PCF. Ground water: Minor, Hardness: NA.

System Class: TBM, Wirth Erkelenz, Hardrock, 9' 9' dia. 25 Hughes Tool/Wirth TCBI roller and tricone cutters. RPM: 8-11, 600 HP Torque, 500 K# thrust. Mucking: Buckets to belt. Haulage: Red. Support: 4" ring and half sets, roof plates and rock bolts.

MDN STUDY SYSTEM DATA SHEET MDN T-M5 Ideat, No. NAST-2 Sheet 2

Lithology: Igneous, biotitic granite, fine grained, with major quartz and

minor feldspar and dark mineral contents.

Uniaxial Compressive Strength: 13 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 152 PCF.

Ground Water: Minor, from fault zones.

Hardness: NA 1-11-72.

TUNNEL DATA:

Size: 10' high x 16' wide x 8', alcove from 9'-9" diameter tunnel.

Ventilation System: 10 KCFM, exhaust, 22" pipe.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 5-10 GPM.

Power System: Not applicable.

Haulage System: Muck, personnel, supplies by rail cars, 36" Gage, 70# rail. Support System: 1" x 7' grouted rock bolts and 13" x 10'-16 gage roof plates.

EXCAVATION DATA:

Conventional Rail Haulage System.

Drilling: 2-S53F, 4' feed, jack legs.

Drill Round: 72 holes, 1 3/4" diameter, 9" av. depth, double V-cut.

Explosives: 300# Gelex #2-60%. Powder Factor, 6.3#/CY.

Blasting: Electrical, zero and 7 regular delays.

Mucking: Diesel front end loader, 1/2 CY.

Guidance: Not applicable.

Abrasiveness N.A. 1/11/72

Pot, Vol. Change, Material

Size - 0.056" : 0

Spec. Gravity, Material

Size = 0.75" : 2.65

ATTERBERG LIMITS, MATERIAL SIZE (-)J. 056 IN.

Liquid Limit 19.50% Plasticity Index 2.09 %

Plastic Limit 17.41%
Toughness Index 0.51

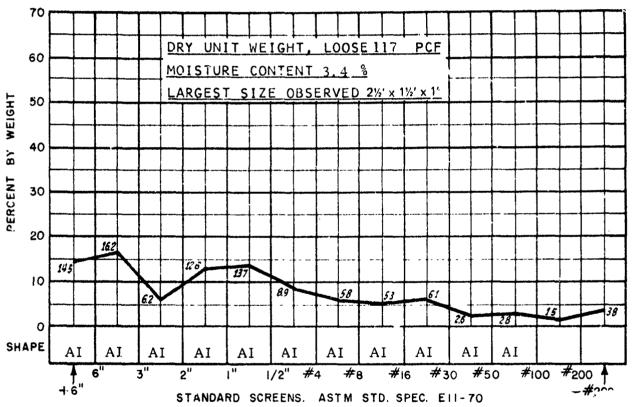
Shrinkage Limit 17, 13 % Flow Index 4, 10

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @ 2.8% Moisture, 39°
Angle Slide Steel Plate @ 2.8% Moisture, 31°

Apparent Cohesion PSF (# 3.0% Moisture, 80 Bulk Density PCF (# 0.0% Moisture, 91.2

Angle/Repose 10 In. Drop @ 2.8% Moisture, 36° Angle Internal Friction @ 3.0% Moisture, 38°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, biotitic, fine grained. Medium strength. RQD: (Est.) 90%. DUW: 152 PCF. Ground water: Minor. Hardness: NA.

System Class: Conventional Rail. 10' high x 16' wide x 8'alcove. Two jack leg drills, 72-9' holes, double V-cut. PF 6.3#/CY. Mucking: Diesel front end loader, 1/2 CY. Haulage: Rail. Support: Grouted rock bolts and roof plates.

MDN STUDY SYSTEM DATA SHEET MDN T-C3 Ident, No. NAST-3 Sheet 2

Lithology: Igneous, granite, fine grained, moderately fractured, major

quartz and minor feldspar and dark mineral contents.

Uniaxial Compressive Strength: 24 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 160 PCF.

Ground Water: Minor, primarily from fault zones.

Hardness: NA 1-11-72.

TUNNEL DATA:

Size: 9'-10" diameter. Grade: (+) 0.22%.

Ventilation System: 10 KCFM, exhaust, 22" pipe to rear of conveyor, 16" to face.

Utility System: 6" air line, 2" water line, 6" punip line.

Water Inflow: 5 to 20 gpm. Power System: 4160/480V.

'age System: Muck, personnel, supplies by rail cars, 36" gage 70# rail. .

Support System: 4" ring and half sets, at 4', 3' and 2' centers in bad ground (approximately 650'), 13" wide x 10' - 16 gage plates secured by 4-1" x 7' grouted bolts as required, (approximately 1200').

EXCAVATION DATA:

Machine: Wirth Erkelenz, Hardrock Model (Modified)*. Weight 67 tens. Cutters: 29 Hughes Tool Tungsten Carbide Button. Gage: 6-11 1/2" TCB roller. Interior: 19-11 1/2" TCB roller. Center: 2-11 1/2" roller and 2-11 1/2" TCB cone.

Rotation: 8 1/2 RPM.

Torque: 600 HP. Thrust: 660 K lbs.

Muck System: Bucket from face, 22" beit conveyor to rear.

Power System: 3-200 HP electric motor driven hydraulic pumps driving

hydraulic motors and cylinders.

Guidance System: Laser.

*Modified by replacement of original by a Hughes Tool Co. cutting head and cutters.

MDN STUDY SYSTEM DATA SHEET T-M5 Ident. No. NAST-4 Sheet 1

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material Size ŊΑ

Spec. Gravity, Material Size

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %. 1 Plasticity Index NA % Plastic Limit NA "" Toughness Index NA Shrinkage Limit NA % Flow Index

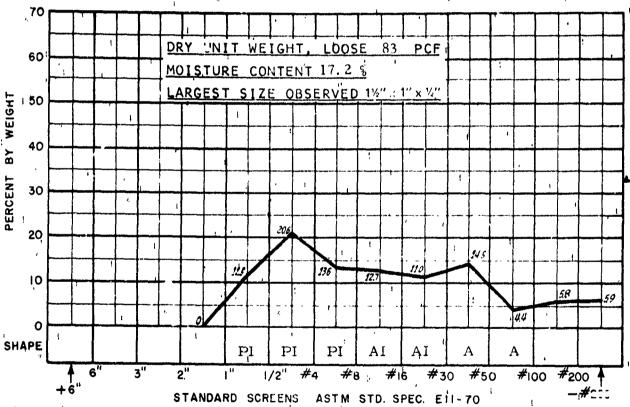
MATERIAL SIZE

IN.

Angle/Repose 1 In. Drop Apparent Cohesion PSF %'Moisture, NA Angle Slide Steel Plate % Moisture, NA

 (α) % Moisture, NA Bulk Density PCF (a) 👊 Moisture, NA

Angle/Repose 10 In. Drop - % Moisture, Angle Internal Friction % Moisture,



MUCK: PCT, BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, fine grained, moderately fractured. High strength. RQD (Est.) 90%. DUW: 160 PCF. Ground water: Minor. Hardness: NA

System Class: TBM, Wirth Erkelenz, Hardrock, with Hughes Tool head, 9' 10" dia. 29 Hughes Tool TCBI roller and cone cutters. RPM: 8 1/2. 600 HP torque, 660 K# thrust. Mucking Buckets to belt. Haulage: Rail. Support: 4" ring and half sets, roof plates and rock bolts. MDN STUDY SYSTEM DATA SLEET MDN T-M5 Ident. No. NAST-1 Sheet 2

Lithology: Igneous, granite, massive, major feldspar and quartz, minor dark, mineral content.

Uniaxial Compressive Strength: 35 KPSI:

RQD: (Estimated) 96%

Dry Unit, Weight: 161 PCF'

Ground Water: Minor, through fractures.

Hardness: NA 1-11-72 .

TUNNEL DATA:

Size: 10' x 10' Horse shoe. Grade 0.22%

Ventilation System: 8 KCFM, exhaust, 22" pipe.

Utility System: 6" air line, 2" water line

Water Inflow: 5-10 gpm.

Power System: 110V. lighting:

Haulage System: Muck and supplies: Eimco 912 diesel.

Support System: 4" WF steel sets @ 4' in 180' approx. at portal end; 1" x 7' grouted rock bolts for approx. 35'.

EXCAVATION DATA:

Conventional Trackless System.

Drilling: Crawler Jumbo, 2-D93 Drifters, 10' feeds.

Drill Round: 48-1 3/4" holes, double V cut, 8' depth.

Explosives: 175# Gelex #2-70%. Powder factor, 6.1#/CY.

Blasting: Electrical, regular delays, zero through #10.

Mucking System: Eimco 912 diesel, front end loader.

Guidance: Transit lines.

Abrasiveness

Pot. Vol. Change, Material 0

Spec. Gravity, Material

N. A. 1/11/72

Size -0.056":

Size = 0.75'': 2.59

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 16.20% Plasticity Index 0, 42 %

Plastic Limit 15.78% Toughness Index 0.14 Shrinkage Limit 13.67%

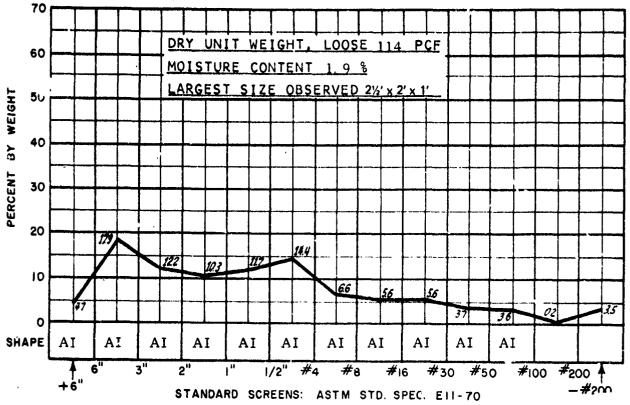
Flow Index 3.00

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @ 0.9% Moisture, 390 Angle Slide Steel Plate @ 0.9% Moisture, 349

Apparent Cohesion PSF (a) 0.9% Moisture, 215 Bulk Density PCF @ 0.0 % Moisture, 106

Angle/Repose 10 In. Drop (w 0.9% Moisture, 36° Angle Internal Friction (a 0.9% Moisture, 460



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, massive, minor dark minerals. Very high

strength. RQD; (Est.) 96%. DUW: 161PCF. Ground water: Minor.

Hardness: NA.

System Class: Conventional Trackless. 10' x 10' arch. Two machine jumbo, 48-8' holes, V-cu' PF 6. 1#/CY. Front end loader mucking and haulage. Support: Steel set: at 41, 25%, occasional rockbolts in 7301.

MDN STUDY SYSTEM DATA SHEET MDN T-C3 Ident. No. GA-1 Sheet 2

Lithology: Igneous, granite, gray, fine grained, moderately jointed with 1.5' to 2' bands of light tan pegmatite and laminated granite gneiss.

Uniaxial Compressive Strength: 32 KPSI.

RQD: (Estimated) 80%. Dry Unit Weight: 162 PCF.

Ground Water: Formations generally dry.

Hardness: NA 1/11/72

TUNNEL DATA:

Size: $10' \times 10'$, Modified Horseshoe. Grade: (+) 1/2%.

Ventilation: 15 KCFM, exhaust, 26" dis. pipe, 125 HP at 7200' from portal.

Utility System: 8" air line, 4" water line, 10" pump line.

Water Inflow: 20 GPM. (As much as 400 GPM in occasional pockets)

Power System: 4160/440V.

Haulage System: Muck, personnel, supplies by rail cars, 36" gage, 75# rail. Three-15T. Goodman locomotives; 2 trains of 11 to 13 cars @ 4.8 CY. Canton car transfer at 50' to 250' from face, passing tracks @1500'.

Support System: 4" WF sets @ 4', 3' and 2' for 23%, 1" x 7' grouted bolts for 17%, Shotcrete: 500 psi @ 18 hrs., 3750 psi @ 28 days, for 16% of 7200'.

EXCAVATION DATA:

Conventional Rail System.

Drilling: Rail mounted hydrojib jumbo, 4-CF99, & 1-CF133 drifters, 12' feed.

Drill Round: 38 holes, 1-5" center hole and 37 at 1 3/4" dia. Spiral Burn Cut, 10 1/2' depth.

Explosives: 183 lbs. Gelex #2-75% x 1-1/2" dia., and 20 lbs. Smooth-tex 70% x 7/8" dia. in upper perimeter holes. Powder factor: 5 1/2#/CY.

Blasting: Electrical, regular delays zero through 10.

Mucking: EIMCO #25, rail, air operated.

Guidance: Laser

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material

Spec. Gravity, Material

Size - 0.056"

Size = 0.75": 2.70

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18.0 % Plasticity Index 1.0 % Plastic Limit 17.0 % Toughness Index 0.23 Shrinkage Limit 13.4 %

Flow Index 4.4

MATERIAL SIZE (-)2.0 IN.

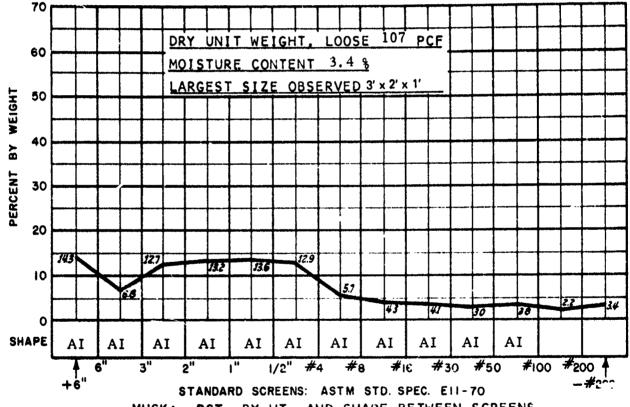
Angle/Repose 1 In. Drop @ 1.3% Moisture, 40° Angle Slide Steel Plate @ 1.3% Moisture, 32°

Apparent Cohesion PSF % Moisture, Bulk Density PCF

% Moisture,

NA

Angle/Repose 10 In. Drop (w 1.3% Moisture, 37° Angle Internal Friction (@ 2.2 % Moisture, 44°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, fine grained, with 1.5' to 2' bands of pegmatite and laminated granite gneiss. High strength. RQD: (Est.) 80%. DUW: 162 PCF.

Ground water: Minor. Hardness: NA.

System Class: Conventional Rail. 10' x 10' arch. Five machine jumbo, 38-10-1/2 holes, burn cut. PF 5.5#/CY. Overhead loader mucking, rail haulage. Support: Steel sets at 2' to 4', 23%, rockbolts 17%, shotcrete 16%, in 7200'.

MDN STUDY SYSTEM DATA SHEET MDN T-C3 Ident. No. H-1

Sheet 2

Lithology: Igneous, granite, gray, gneissic, moderately jointed.

Uniaxial Compressive Strength: 39 KPSI

RQD: (Estimated) 80% Dry Unit Weight: 164 PCF

Ground Water: Generally dry - occasional flows through fractures

Hardness: NA 1/11/72

TUNNEL DATA:

Size: $10^{1} \times 10^{1}$ modified horseshoe. Grade: (+) 1/2%

Ventilation System: 8 KCFM exhaust, 26" pipe, 150 HP at 10,000 from

Utility System: 8" air line, 4" water line, 10" pump line

Water Inflow: 20-400 GPM, normal 135 GPM

Power System: 4160/480/240V.

Haulage System: Muck, personnel, supplies by rail cars. 36" gage, 75# rail. Three-15T. Goodman locomotives, 3 trains of 5 to 7 cars @ 4.8 cy. Canton car transfers at 50' to 250' from face, passing tracks @ 1500' to 2500'.

Support System: Minor rock bolt support for last 2500'.

EXCAVATION DATA:

Conventional Rail System

Drilling: 4 boom Hydojib jumbo, 4-CF99 + 1-CF133 drifters, 12' contin. feed.

Drill Round: 36-40 holes, 1 3/4" diameter, 11' deep, spiral burn cut with 5" center hole.

Explosives: 200 lbs. 75% Gelex #2, 25 lbs. 30% Dupont 7/8" x 24" in back holes.

Blasting: Electrical, regular delays 0-10, Powder factor 5.6#/CY.

Mucking: EIMCO #25, rail, air operated

Guidance: Laser

Abrasiveness N.A. 1/11/72

Pot. Vol. Change, Material

Size -0.056'':

Spec. Gravity, Material

Size -0.75^{37} : 2.60

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 18. 10 % Plasticity Index 0. 15 %

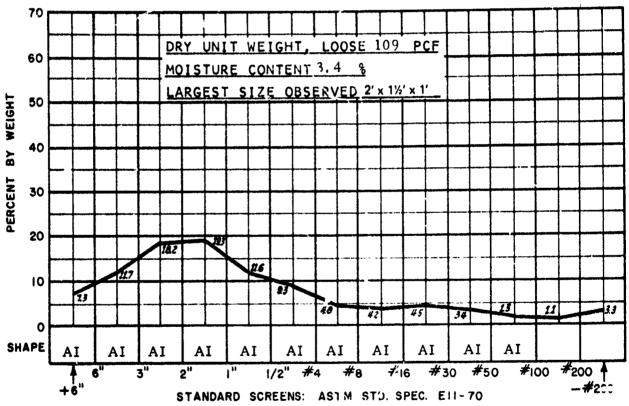
Plastic Limit 17. 95 % Toughness Index 0.04 Shrinkage Limit 11.00% Flow Index 3.20

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop (3.8% Moisture, 38°)
Angle Slide Steel Plate (3.8% Moisture, 38°)

Apparent Cohesion PSF (# 2.6 % Moisture, 30 Bulk Density PCF (# 0.0 % Moisture, 105

Angle/Repose 10 In. Drop @ 3,8% Moisture, 35° Angle Internal Friction @ 2,6% Moisture, 44°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Granite, gneissic, moderately jointed. Very high strength. RQD: (Est.) 80%. DUW: 164 PCF. Ground water: Minor. Hardness: NA.

System Class: Conventional Rail. 10' x 10' arch. Five machine jumbo, 36 to 40 - 11' holes, burn cut. PF 5.6#/CY. Overhead loader mucking - rail haulage. Support: occasional rockbolts 7200' to 10,000'.

MDN STUDY SYSTEM DATA SHEET MDN T-C3

Ident. No. H-2

Sheet 2

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry.

Uniaxial Compressive Strength: 25 KPSI

RQD: (Estimated) 83% Dry Unit Weight: 162 PCF. Ground Water: None apparent

Hardness: NA 1/11/72

TUNNEL DATA:

Size: 18' wide x 16' high, arched back. Grade: (+) 51/2%.

Ventilation System: 76 KCFM, pressure in heading, 48" pipe and tubing. Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage, surface fans.

Utility System: 6" compressed air, 2" water.

Water Indow: None apparent.

Power System: 4160/220V for fans, 110 volt lighting.

Haulage System: Wagner ST8 Scooptram to raise, chute loaded into rail

mounted skip. Personnel and supplies by diesel truck.

Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts @ 4'.

EXCAVATION DATA:

Conventional Trackless System

Drilling: Gardner-Denver 3 boom jumbo, 1 PR123 and 2 DH 123 drifters, 12' feeds.

Drill Round: 47 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 10 1/2" deep.

Explosives: $25\# - 1.1/2 \times 8''$, 60% or 75% primers, $25\# - 7/8'' \times 16''$, 30% in trim holes, $40\# - 1.1/2'' \times 16''$, 45% in ℓ hole burn cut, and 275# AN/FO in remainder of round. Powder factor: 4#/cy.

Blasting: Electrical, regular delays, 0 through 15.

Mucking: Scooptram. Guidance: Laser.

MDN STUDY SYSTEM DATA SHEET T-Cl Ident, No. 1K-1 Sheet 1

Abrasiveness

Pot. Vol. Change, Material

Spac. Gravity, Material

N. A. 1/11/72

Size -0.056'':

Size -0.75": 2.85

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

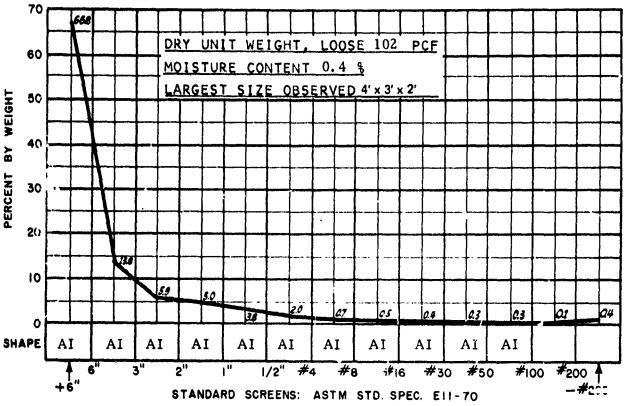
Liquid Limit 18. 10% Plasticity Index 0.12 % Plastic Limit 17. 98 % Toughness Index 0.30 Shrinkage Limit 17.69% Flow Index 3.90

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @ 0.8% Moisture, 330 Angle Slide Steel Plate @ 0.8% Moisture, 29°

Apparent Cohesion PSF (a) 0.4% Moisture, 435 Bulk Density PGF (a) 0.0% Moisture, 97.3

Angle/Repose 10 In. Drop (a) 0.8 % Moisture, 30° Angle Internal Friction @ 0.4 % Moisture, 43°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry. High strength. RQD:(Est.) 83%. DUW: 162 PCF. Ground water: Dry. Hardness: NA.

System Class: Conventional Trackless. 18' wide x 16' arch. Three boom jumbo, 47-10 1/2' holes, burn cut. PF 4#/CY. Scooptram mucking and haulage to raiserail skip to surface. Support: Roof plates and rock bolts at 4'.

MDN STUDY SYSTEM DATA SHEET MDN T-C1 Identa No. LK-1 Sheet 2

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry, with minor steeply inclined joints.

Uniaxial Compressive Strength: 28 KPSI

RQD: (Estimated) 83%
Dry Unit Weight: 165 PCF
Ground Water: None apparent

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 18' wide x 16' high, arched back. Grade: (+) 2%.

Ventilation System: 22 KCFM, pressure in heading, 48" pipe and tubing. Underground fans 48", 150 HP, 2 stage. Exhaust in return air way to 3-54", 150 HP, 2 stage surface fans.

Utility System: 6" compressed air, 2" water.

Water Inflow: None apparent.

Power System: 4160/220 for pumps and fans, 110V lighting.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station, rail mounted skip to surface. Personnel and supplies by diesel truck.

Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts @ 4'.

EXCAVATION DATA:

Conventional Trackless system.

Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds. Drill Round: 47 holes, 1 3/4" diameter, including 6 hole burn cut, and

1 center hole, 4" diameter, all 10 1/2' deep.

Explosives: 25#-1 $1/2" \times 8"$, 60% or 75% primers, $25\#-7/8" \times 16"$, 30% in trim holes, 40#-1 $1/2" \times 16"$, 45% in 6 hole burn cut, and 275# AN/FO in remainder of round. Powder factor: 4#/CY.

Blasting: Electrical, regular delays, 0 through 15.

Mucking: Scooptram.

Guidance: Laser.

W

61

. 1

Abrasiveness

Pot. Vol. Change, Material

Sp.c. Gravity, Material

N. A. 1/11/72

Size -0.056"

Size -0.75" : 2.73

ATTERBERG LIMITS, MATERIAL SIZE (-) 0.056 IN.

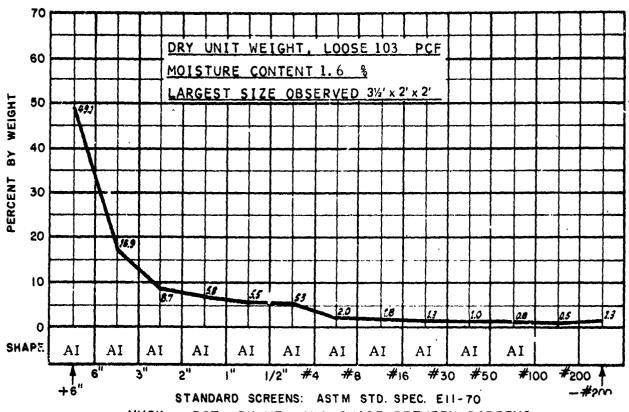
Liquid Limit20.50 % Plasticity Index 0.36 % Plastic Limit 19, 14 % Toughness Index 0.058 Shrinkage Limit 17.29 % Flow Index 6.2

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @ 4.7% Moisture, 43° Angle Slide Steel Plate @ 4.7% Moisture, 33°

Apparent Cohesion PSF @4.9% Moisture, 210 Bulk Density PCF @ 0.0 % Moisture, 97.6

Angle/Repose 10 In. Drop @4.7 % Moisture, 420 Angle Internal Friction @4.9% Moisture, 390



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry minor steep angle joints. High strength. RQD:(Est.) 83%. DUW: 165 PCF. Grou water: Dry. Hardness: NA.

System Class: Conventional Trackless. 18' wide x 16' arch, Three boom jumbo, 47 - 10 1/21 holes, burn cut. PF 4#/CY. Scooptram mucking and haulage, rail skip to surface. Support: Roof plates and rock bolts at 4'.

MDN STUDY SYSTEM DATA SHEET MDN T-C1 Ident. No. LK-2 Sheet 2

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry.

Uniaxial Compressive Strength: 32 KPSI

RQD: (Estimated) 92%

Dry Unit Weight: 165 PCF

Ground Water: None apparent.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 12' diameter vertical bore hole, reamed from 1312' to 1212' below collar, from a 13 7/8" diameter pilot hole.

Ventilation System: None in bore hole.

Utility System: 5 to 10 gpm. Water for dust suppression through pilot hole.

Water Inflow: None apparent

Power System: 440V to surface drive motors.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/

rail mounted skip to surface. Support System: None in bore hole.

EXCAVATION DATA:

Machine: Robbins H81R Raise Drill. Weight 49 tons. Cutters: 27 Robbins, Steel Disc. Gage: 3-12". Center: 1-11". Interior: 19-12" single and 2-11" twin. Two sets of three 12" dia. TCB roller stabilizers are installed on third points below the cutter head.

Rotation, cutter head: 6 RPM.

Torque: 383.5 K Foot Lbs.

Reaming Pull: Total 814K Lbs @ 2400 PSI, net 490 K to 510 K#.

Muck Disposal: Scooptram, underground.

Power System: 3-440V, 100 HP constant torque motors, 1.667: 1 gathering box ratio.

Guidance System: Survey in pilot hole.

MDN STUDY SYSTEM DATA SHEET T-M5 Ident. No. LK-5 Sheet 1

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material Size : NA

Spec. Gravity, Material
Size NA

ATTERBERG'LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %
Plasticity Index NA %

Plastic Limit: NA %
Toughness Index NA

Shrinkage Limit NA %
Flow Index NA

MATERIAL SIZE

IN.

Angle/Repose l In. Drop

@ % Moisture, NA

Angle Slide Steel Plate

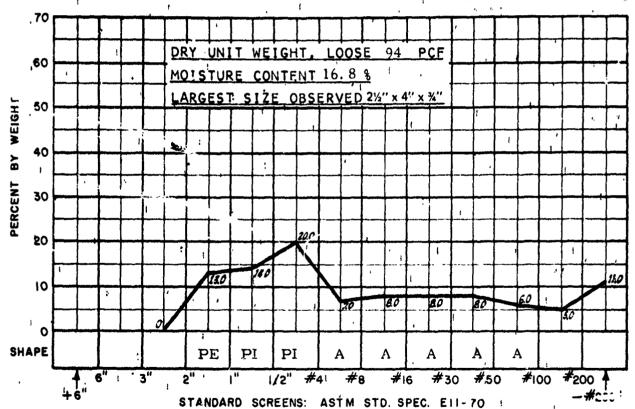
@ % Moisture, NA

Apparent Cohesion PSF Angl

(a) % Moisture, NA (a)

Bulk Density PCF Angl

(a) % Moisture, NA (a)



MUCK: POT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

<u>Pock Class</u>: Igheous: Quartz monzonite, biotitic, fine to medium grained porphyry. High strength., RQD:(Est.) 92%, DUW: 165 PCF. Ground water: Dry. Hardness: NA.

System Class: RBM, Robbins H81R, 12' dia. 27 Robbins disc cutters, 6 RPM, 383.5 Kft. # torque, 500K # pull average. Mucking and haulage: Scooptram, underground, rail skip to surface Support: None.

Lithology: Igneous, biotitic quartz monzonite, fine to medium grained porphyry, frequent flat angled joints,

Uniaxial Compressive Strength: (Estimated) 15 KPSI.

RQD: (Estimated) 86%.

Dry Unit Weight: 137 PCF.

Ground Water: None apparent.

Hardness: N.A. 1/11/72

TUNNEL DATA:

Size:, 4' diameter vertical bore hole reamed from 298' to 286' below collar from a 13.7/8" diameter pilot hole.

Ventilation System: Not applicable.

Utility System: 5 to 10 gpm water for dust suppression through pilot hole.

Water Inflow: None apparent.

Power System: 440V to surface drive motors.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/ rail mounted skip to surface. Personnel and supplies by diesel truck. I Support System: None in bore hole.

EXCAVATION DATA:

Machine: Robbins H81R Raise Drill. Weight: 49 tons.

Cutters: 11-Robbins, Steel Disc. Gage: 1-12" twin. Center 1-12" single. Interior: 4-12" twin. Three 12" TCB roller stabilizers are installed at third points below the cutter head.

Rotation, Cutter head: 6 RPM

Torque: 383.5 K Foot/lbs.

Reaming Pull: Net 170 K to 205 K#.

Muck Disposal: Scooptram underground.

Power System: 3-440V, 100 HP constant torque motors, 1.667: 1 gathering

box ratio.

Guidance System: Survey in pilot hole.

MDN STUDY SYSTEM DATA SHEET T-M5 Ident. No. LK-6 Sheet 1

4 1

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material

Spec. Gravity, Material

Size

NA

Size NA

ATTERBERG LIMITS, MATERIAL SIZE

IN

Liquid Limit NA Plasticity Index NA % Plastic Limit NA Toughness Index NA Shrinkage Limit NA Flow Index NA

MATERIAL SIZE

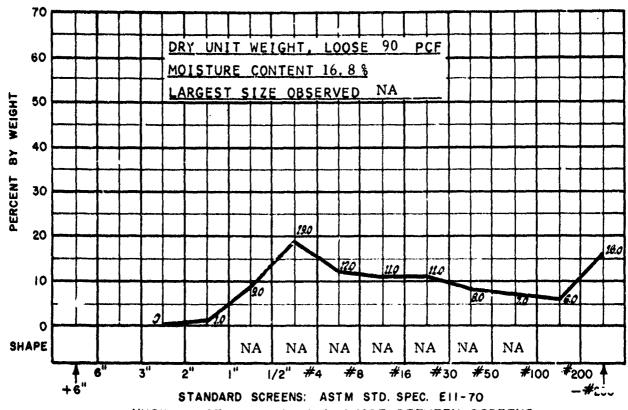
IN.

Angle/Repose 1 In. Drop % Moisture, NA Angle Slide Steel Plate % Moisture, NA

Apparent Cohesion PSF (a) % Moisture, NA Bulk Density PCF

% Moisture, NA

Angle/Repose 10 In. Drop % Moisture, Angle Internal Friction % Moisture,



PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Igneous: Quartz monzonite, biotitic, fine to medium grained porphyry, frequent flat angled joints. Medium strength (Est.). RQD:(Est.) 86%. DUW: 137 PCF. Ground Water: Dry. Hardness: NA.

System Class: RBM, Robbins H81R, 4' dia. 11 Robbins disc cutters. 6 RPM, 38.5 K ft. # torque 185K # pull (average). Mucking and Haulage: Scooptram und rground, rail skip to surface. Support: None.

MDN STUDY SYSTEM DATA SHEET MDN T-M5

Ident. No. LK-6

Sheet 2

Lithology: Metamorphic, granitic gneiss, highly metamorphosed, moderately

to highly fractured, highly silicified. Uniaxial Compressive Strength: 9 KPSI.

RQD: (Estimated) 10%. Dry Unit Weight: 174 PCF.

Ground Water: Minimal-grains to other workings.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 13', round, Grade (+) 1/4 percent.

Ventilation System: 10 K CFM. exhaust, 24" pipe

Utility System: 4" air line, 2" water line.

Water Inflow: 5-10 gpm. Power System: 4160/480V.

Haulage System: Personnel, muck, supplies by rail cars.

Support System: None.

EXCAVATION DATA:

Machine: Calweld, Hardrock model, #40.

Weight: 200 tons.

Cutters: 19-Smith Tool Tungsten Carbide Button, Gage: 6-GT-SH 8 roller.

Center: 1-TGB tricone, interior: 12-GT-MH8 roller.

Rotation: Center cutter-26 RPM, Head-12 RPM.

Torque: 347 K #.
Thrust: 1,128 K #.

Muck Collection: Buckets from face, 24" conveyor to rear.

Power System: 480V Electro-Hydraulic.

Guidance System: Laser.

Abrasiveness

Pot. Vol. Change, Material

Spec. Gravity, Material

N. A. 1/11/72

Size : NA

Size : NA

AT PERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %
Plasticity Index NA %

Plastic Limit NA % Toughness Index NA Shrinkage Limit NA % Flow Index NA

MATERIAL SIZE

IN.

Angle/Repose 1 In. Drop

% Moisture, NA

Angle Slide Steel Plate

% Moisture, NA

Apparent Cohesion PSF

Moisture, NA

Bulk Density PCF

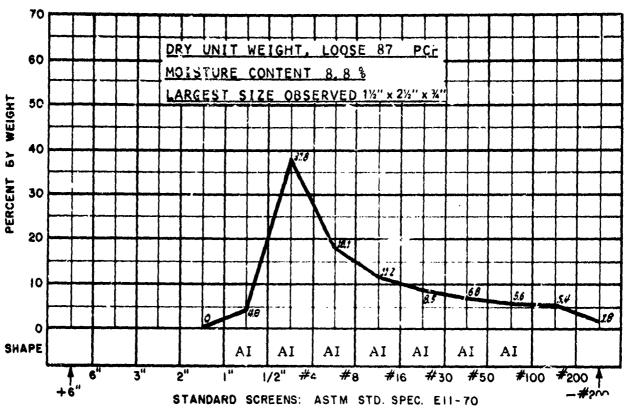
Moisture, NA

Angle/Repose 10 In. Drop

Moisture, NA

Angle Internal Friction

Moisture, NA



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Granitic gneiss, highly metamorphosed and silicified, mode ately to highly fractured. RQD: (Est.) 10%. DUW: 174 PCF. Medium strength. Ground water: Dry. Hardness: NA

System Class: TBM, Calweld #40, 13' dia. 19 Smith Tool TCBI roller and tricone cutters. RPM: Head 12, center 26. 347K ft # torque, 1 128K # thrust.

Mucking: Buckets to belt. Haulage; Rail. Support: None.

MDN STUDY SYSTEM DATA SHEET MDN T-M5 Ident. No. CL-1 Sheet 2

Lithology: Metamorphic, interlayered transition between quartzite and tactite. Moderately to strongly altered metasediments, with replacement pyrite, chalcopyrite and magnetite, and a high percentage of silicates, very fine to medium grained.

Uniaxial Compressive Strength: 26 KPSI.

RQD: (Estimated) 80% Dry Unit Weight: 178 PCF. Ground Water: None apparent

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 16' wide x 14 1/2' high, arched back. Grade: (+) 2%.

Ventilation System: 52 KCFM, pressure in heading, 48" pipe and tubing.

Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.

Utility System: 6" compressed air, 2" water.

Water Inflow: None apparent.

Power System: 4160/220V for pumps and fans, 110V lighting.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail

mounted skip to surface. Personnel and supplies by diesel truck. Support System: 13 1/2" x 9' roof plates, 6' x 3/4" rock bolts at 4'.

EXCAVATION DATA:

Conventional Trackless System.

Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds. Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut, and 1 center hole, 4" diameter, all 6' deep.

Explosives: $15\# - 1\ 1/2" \times 8"$, 60% or 75% as primers, $15\# - 7/8" \times 16"$, 30% in trim holes, $25\# - 1\ 1/2" \times 16"$, 45% in 6 hole burn cut, 150# AN/FO in remainder of round. Powder factor 5#/cy.

Blasting: Electrical, regular delays, 0 through 15.

Mucking: ScoopCram. Guidance: Laser.

MDN STUDY SYSTEM DATA SHEET T-C1 Ident. No. LK-3 Sheet 1

Abrasiveness N. A. 1/11/72

Pot. Vol. Change, Material Size -0.056": 0

Spec. Gravity, Material Size -0.75¹¹ : 3.21

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

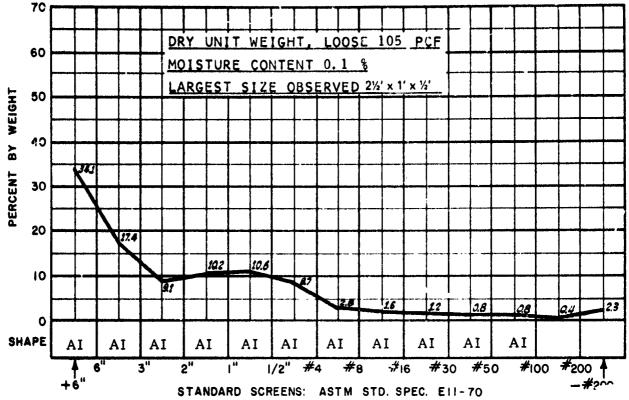
Liquid Limit 18.25 % Plasticity Index 0.33 %

Plastic Limit 17.92 %
Toughness Index 0.06

Shrinkage Limit 17.80 % Flow Index 5.50

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @ 1.5% Moisture, 30° Angle Slide Steel Plate @ 1.5% Moisture, 29° Apparent Cohesion PSF @ 0.4% Moisture, 175 Bulk Density PCF @ 0.0% Moisture, 117.8 Angle/Repose 10 In. Drop @ 1.5% Moisture, 29°
Angle Internal Friction @ 0.4% Moisture, 41°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Quartzite-tactite transition, very fine to medium grained, with replacement sulphides and magnetite, high in silicates. High strength. RQD:(Est.) 80%. DUW: 178 PCF. Ground water: Dry. Hardness: NA. System Class: Conventional Trackless. 16' wide x 14-1/2' arch. Three boom jumbo, 42-6' holes, burn cut. PF 5#/CY. Scooptram mucking and haulage, rail skip to surface. Support: Roof plates and rock bolts at 4'.

MDN STUDY SYSTEM DATA SHEET MDN T-C1 Ident. No. LK-3 Sheet 2

Lithology: Metamorphic, tactite, strongly altered calcareous metasediments, with replacement pyrite, chalcopyrite and magnetite, and a high percentage of silicates, fine to very fine grained.

Uniaxial Compressive Strength: (Estimated) 1218 PSI.

RQD: (Estimated) 70% Dry Unit Weight: 181 PCF Ground Water: None apparent.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 15' wide x 14' high, arched back. Grade: (+) 2%.

Ventilation System: 50 KCFM, pressure in heading, 48" pipe and tubing. Underground fans 48", 150 HP, 2 stage. Exhaust in return airway to 3-54", 150 HP, 2 stage surface fans.

Jtility System: 6" compressed air, 2" water.

Water Inflow: None apparent.

Power System: 4160/220V for pumps and fans, 110V lighting.

Haulage System: Wagner ST-8 Scooptram to surge pile at shaft station/rail

mounted skip to surface. Personnel and supplies by diesel truck.

Support System: 6" WF Steel Sets at 5'.

EXCAVATION DATA:

Conventional Trackless System.

Drilling: Gardner-Denver 3 boom jumbo, 3 PR123 drifters, 12' feeds.

Drill Round: 42 holes, 1 3/4" diameter, including 6 hole burn cut and 1 center hole, 4" diameter; all 6' deep.

Explosives: 15#-1 $1/4" \times 8"$, 60% or 75% as primers, $15\#-7/8" \times 16"$ 30% in trim holes, 25#-1 $1/2" \times 16"$, 45% in 6 hole burn cut, 150# AN/FO in remainder of round. Powder factor 5.5#/CY.

Blasting: Electrical, regular delays, 0 through 15

Mucking: Scooptram.

Guidance: Laser

Abrasiveness N.A. 1/11/72 Pot. Vol. Change, Material

Size : NA

Spec. Gravity, Material

Size

NΑ

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %
Plasticity Index NA %

Plastic Limit NA %
Toughness Index NA

Shrinkage Limit NA %

Flow Index NA

MATERIAL SIZE

IN.

Angle/Repose 1 In. Drop

@ % Moisture, NA

Angle Slide Steel Plate

@ % Moisture, NA

Apparent Cohesion PSF

(d) % Moisture, NA

Bulk Density PCF

Bulk Density PCF

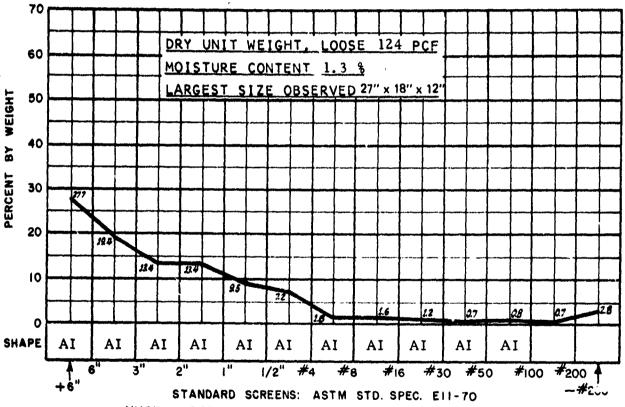
(a) % Moisture, NA

Angle/Repose 10 In. Drop

(a) % Moisture, NA

Angle Internal Friction

(a) % Moisture, NA



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Tactite, fine to very fine grained, with replacement sulphides and magnetite, high in silicates. Medium strength (Est.).

RQD:(Est.) 70%. DUW: 181 PCF. Ground water: dry. Hardness: NA.

System Class: Conventional Trackless. 15' wide x 14', arch. Three boom jumbo, 42-6' holes, burn cut. PF 5.5#/CY. Scooptram mucking and haulage, rail skip to surface. Support: Steel sets at 5'.

MDN STUDY SYSTEM DATA SHEET MDN T-C2 Ident, No. LK-4 Sheet 2

Lithology: Metamorphic, interlayered bands of hematite and martite, highly jointed, normally flat lying, but often highly folded. Natural iron over 60%, moisture 9%, silica 5%.

Uniaxial Compressive Strength: 7 KPSI.

RQD: (Estimated) 10% Dry Unit Weight: 207 PCF

Ground Water: Formation generally dry.

Hardness: NA 1-11-72

TUNNEL DATA:

9'-11 1/2" diameter; normal grade: 0%.

Ventilation System: 3 KCFM, pressure, 8" dia. tube, 5 HP @ 250' from main level.

Utilities: 2" air line, 1" water line, 2-1 1/2" pressure and 1-3" return hydraulic lines.

Water Inflow: None

Power System: 110V lighting, 440V to scraper hoist.

Muck Haulage: 30 HP hoist, and 42" scraper to raise, all rail on main level.

Personnel, rail and ladders; supplies by rail cars and hoist.

Support: Continuous; 9'-6" dia. x 4" WF sets at 45".

EXCAVATION DATA:

Machine: Calweld Oscillator. Wt: 69 K#.

Cutters: 278 Carboloy drag bits. Gage: 20 rippers (experimental).

Interior: 258 "J" tools.

Rotation: 8 RPM Torque: 1200 K ft.#.

Thrust: 300 K# max., 285 K# operating.

Anchorage: Thrust on installed scts, 285K# operating.

Muck Collection: Flight conveyor to lear of machine, removal by scraper

Power System: Remote power unit; 2-90 gpm, 2500 psi hydraulic pumps and 125 HP motors on main level; thrust and rotation through hydraulic cylinders.

Guidance System: Survey.

MDN STUDY SYSTEM DATA SHEET T-M6 Ident, No. MB-1 Sheet 1

1 1

2 1

Abrasiveness N. A. 1/11/72

Pot. Vol. Change, Material Size-0.056": 0

Spec. Gravity, Material Size - 0.75": 4.34

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

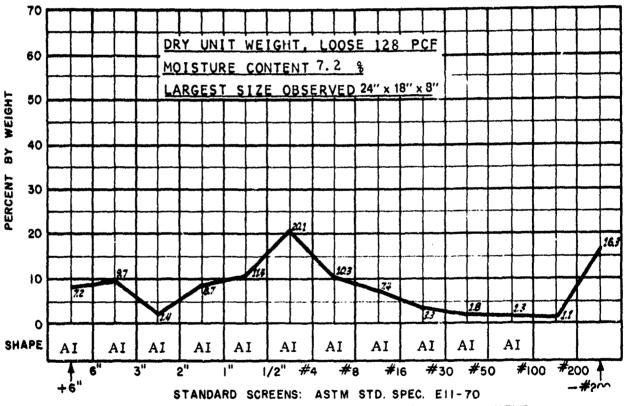
Liquid Limit 17.8 %
Plasticity Index 2.7 %

Plastic Limit 15.1 %
Toughness Index 0.66

Shrinkage Limit 13.9 % Flow Index 4.1

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @ 6.2% Moisture, 37° Angle Slide Steel Plate @ 6.2% Moisture, 31° Apparent Cohesion PSF @6.9 % Moisture, 235 Bulk Density PCF @0.0 % Moisture, 141 Angle/Repose 10 In. Drop & 6.2 % Moisture, 35°
Angle Internal Friction & 6.9 % Moisture, 35°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Metamorphic: Hematite and martite interlayered, highly jointed, bedding normally flat, often highly folded. Low strength. RQD (Est.) 10%. DUW: 207 PCF. Ground water: Dry. Hardness: NA.

System Class: TBM, oscillator, Calweld #53, 9'-11-1/2" diam. 278 Carboloy drag bits. 8 RPM, 1200 K, ft # torque, 285 K # thrust. Mucking: Flight conveyor and scraper to raise. Haulage: Rail. Support: Continuous, 9' 6" dia. x 4" H sets at 45".

MDN STUDY SYSTEM DATA SHEET MDN T-M6 Ident, No. MB-1 Sheet 2

Lithology: Metamorphic, gray mica schist, occasional quartz seams, mica

varies from dense fine grained to extremely coarse.

Uniaxial Compressive Strength: 11 KPSI.

RQD: (Estimated) 30% Dry Unit Weight: 165 PCF

Ground Water: Major inflow occurs in faults and fault zones.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 11', diameter. Grade: (+) 1 to 3%

Ventilation System: 4 KCFM exhaust 14" pipe.

Utility System: 4" waterpipe, no airline. Water Inflow: 60 gpm, drains in ditch

Power System: 4160/480V

Haulage System: Muck, personnel, supplies by rail cars.

Support System: None, occasional semi-circular plates pinned at spring

line in fault zones

EXCAVATION DATA:

Machine: Jarva, Mark 11-1100, Total Weight: 70 tons

Cutters: 36 Reed, type QK steel multiple disc. Gage: 8 triple disc.

Center: 2-triple disc. Interior: 26 triple disc.

Rotation: Cutterhead, 10 RPM

Torque: 244 K ft. #

Anchor Pressure: Maximum 3, 402 K#.

Thrust: 1, 134 K#.

Muck System: Buckets from face, belt to rear

Power System: Four 100 HP, 480V motors drive head, 40 HP 480V motor

driven hydraulic system. Guidance System: Laser

MDN STUDY SYSTEM DATA SHEET T-M4 Ident. No. QL-1 Sheet 1

Abrasiveness N. A. 1/11/72

Pot. Vol. Change, Material Size -0.056" / 0

Spec. Gravity, Material Size -0.75": 2.57

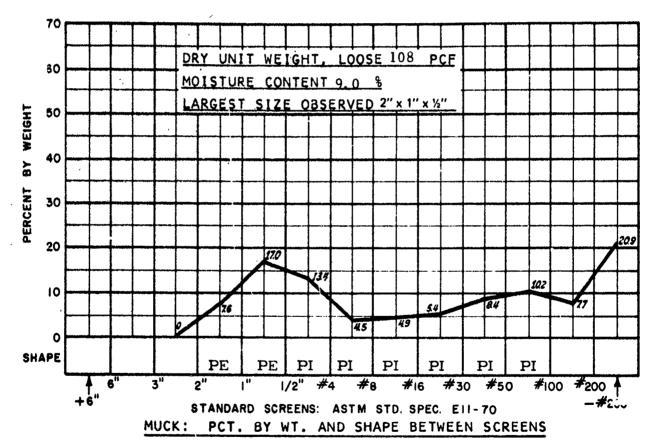
ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 24.0 % Frasticity Index 0.7 % Plastic Limit 23.3 % Toughness Index 0.17 Shrinkage Limit 22.7 % Flow Index 4.0

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @9,8 % Moisture, 39 Angle Slide Steel Plate @8.4 % Moisture, 40°

Apparent Cohesion PSF (a) 9.3 % Moisture, 125 Bulk Density PCF (a) 0.0 % Moisture, 75 Angle/Repose 10 In. Drop @ 9.8% Moisture, 37° Angle Internal Friction @ 9.3% Moisture, 30°



SUMMARY

Rock Class: Metamorphic: Mica schist, dense, fine grained to extremely coarse occasional quartz seams. Medium strength. RQD (Est.) 30%. DUW: 165 PCF.

Ground water: Minor inflows at fault zones. Hardness: NA.

System Class: TBM, Jarva Mark 11-1100, 11' dia 36 Reed triple discs. RPM: 10. Torque: 244 K ft #. Thrust: 1,134 K #. Mucking: Buckets to belt. Haulage: Rail. Support: Minor, semi-circular plates in fault zones.

MDN STUDY SYSTEM DATA SHEET MDN T-M4 Ident. No. QL-1 Sheet 2

Lithology: Sedimentary, sandstone, fine grained, well compacted light brown, over 50 percent quartz.

Uniaxial Compressive Strength: 16 KPSI.

RQD: 92%.

Dry Unit Weight: 171 PCF

Ground Water: Dry. Hardness: Shore 61.

TUNNEL DATA:

Size: 18'-1" dia. Grade (-) 7%

Ventilation System: 17 K CFM, exhaust, 36" dia. pipe, 75 HP @ 4100.

Utility System: 2" water line, 4" pump line. No air line - compressor on

machine.

Water Inflow: 5-10 gpm Power System: 4160/480V

Haulage System, Muck: 390' of 30" "piggy back" conveyor supported by a monorail advances with the TBM, discharges on a 36" conveyor suspended from the back of the tunnel. Supply and Personnel: Diesel jeeps and trucks.

Support System: 6" x 8.2# channels x 9.5' or 13.5' @ 4' or 2', secured by 4-5/8" x 4' rock bolts. Channels also support monorail.

EXCAVATION DATA:

Machine: Robbins 181-122 Weight: 260 tons.

Cutters: 47 Robbins, Steel Disc. Gage: 5-12". Center: 1-7 1/2" triple,

Interior: 41-12".

Rotation: 4 1/2 RPM (Center integral with head)

Torque: 1200 HP input

Thrust: 1,580 K# max., 1,200K# operating.

Muck Collection: Buckets fixed to head, discharging on a 30" conveyor. Power System: Six-480V., 200 HP motors drive head. Hydraulic pumps

power thrust and anchor cylinders.

Guidance System: Laser.

MDN STUDY SYSTEM DATA SHEET T-M2 Ident. No. 5-1 Sheet 1

MUĆK DATA

Abrasiveness N.A. 1/11/72

Pot. Vol. Change, Material, Size -0.065" : 0

Spec. Gravity, Material Size -0.75" : 2.73

ATTERBFRG L(MITS, MATERIAL SIZE (-)0.185 IN.

Liquid Limit 16.90 % 'Plasticity Index 1.40 %

Plastic Limit 15.50 % Toughness Index 0.28

Shrinkage Limit 15.18 % Flow Index 5.0

MATERIAL SIZE (-)2.0 IN.

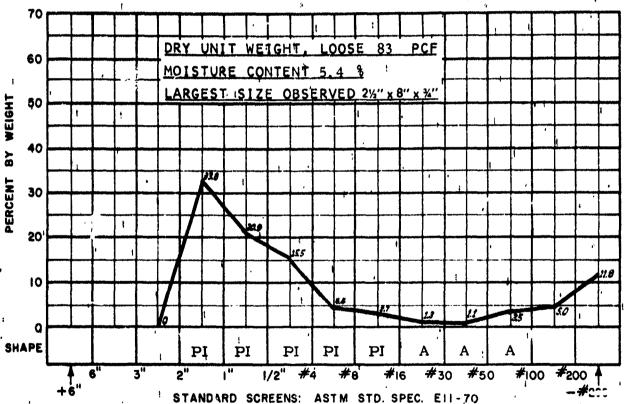
Angle/Repose l' In. Drop @ 6.3% Moisture, 35° Angle Slide Steel Plate @ 6.3% Moisture, 28° Apparent Cohesion PSF

(a) % Moisture, NA

Bulk Density PCF

(b) % Moisture, NA

Angle/Repose 10 In. Drop (# 6.3 % Moisture, 290) Angle Internal Friction (# 4.8 % Moisture, 290



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, fine grained, well compacted, over 50% quartz. High strength. RQD: 92%. DUW: 171 PCF. Ground water: Dry.

Hardness: Shore 61.

System Class: TBM, Robbins 181-122, 18'-1" dia. 47 Robbins disc cutters.
4-1/2 RPM, 1200 HP torque, 1,200 K# thrust. Mucking: Buckets to belt conveyor. Haulage: Traveling conveyor - suspended conveyor - skip to surface. Support: Channels and rock bolts at 4' or 2', continuous.

MDN STUDY SYSTEM DATA SHEEL MDN T-M2

1DN **T-M2** Ident. No. 5-1

Sheet 2

Lithology: Sedimentary, sandstone, fine grained, well compacted light brown, over 50 percent quartz.

Uniaxial Compressive Strength: 16 KPSI.

RQD: 92%.

Dry Unit Weight: 171 PCF.

Ground Water: Dry. Hardness: Shore 61.

TUNNEL DATA:

Size: 18'-1" dia. Grade (+) 2%.

Ventilation System: 17 K CFM, exhaust, 36" dia, pipe, 75 HP @ 4800'.
Utility System: 2" water line, 4" pump line. No air line - compressor on machine.

Water Inflow: 5-10 gpm.

Power System: ,4160/480V.

Haulage System, Muck: 390' of 30" "piggy back" conveyor supported by a monorail advances with the TBM, discharges on a 36" conveyor suspended from the back of the tunnel. Supply and Personnel: Diesel jeers and trucks.

Support System: 6" x 8.2# channels x 9.5' or 13.5',@ 4' or 2', secured by 4-5/8" x 4' rock bolts. Channels also support monorail.

EXCAVATION DATA:

Machine: Robbins 181-122 Weight: 260 tons.

Cutters: 47 Robbins, Steel Disc. Gage: 5-12". Center: 1-7 1/2" triple,

Interior: 41÷12".

Rotation: 4 1/2 RPM (Center integral with head)

Torque: 800 HP Input

Thrust 1,580 K#'max., 1,200K# operating.

Muck Collection: Buckets fixed to head, discharging on a 30" conveyor.

Power System: Four-480V., 200 HP motors drive head. Hydraulic pumps

power thrust and anchor cylinders.

Guidance System: Laser.

MDN STUDY SYSTEM DATA SHEET T'-M2

1.

Ident. No. 7-2 Sheet 1

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material

Spec. Gravity, Material

Size -0.056" : Size -0.75" : 2.63

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 23.0 % Plasticity Index 5.37%

Plastic Limit 17, 63 % Toughness Index 0.78 Shrinkage Limit 17.58%

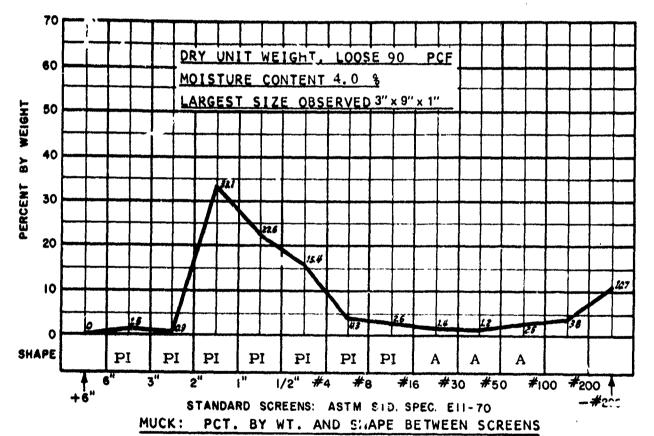
Flow Index 6.90

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @ 2.6% Moisture, 32° Angle Slide Steel Plate @ 2.6% Moisture, 29°

Apparent Cohesion PSF (a) 2.8 % Moisture, 0 Bulk Density PCF @ 0.0 % Moisture, 92.8

Angle/Repose 10 In, Drop (w 2.6 % Moisture, 31° Angle Internal Friction (w 2.8 % Moisture, 44°



SUMMARY

Rock Class: Sedimentary: Sandstone, fine grained, well compacted, over 50% quartz. High strength. RQD: 92%. DUW: 171 PCF. Ground water: Dry.

Hardness: Shore 61.

System Class: TBM, Robbins 181-122, 18' -!" dia. 47 Robbins disc cutters. 4-1/2 RPM, 800 HP torque, 1,200 K# thrust. Mucking: Buckets to belt conveyor. Haulage: Traveling conveyor - suspended conveyor - skip to surface.

Support: Channels and rock bolts at 4' or 2', continuous.

MDN STUDY SYSTEM DATA SHEE " MDN T-M2

Ident, No. 7-2

Sheet 2

Lithology: Sedimentary, "shale", massive to thinly-laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Grain size varies from fine to coarse, quartz content from 24 to 33%.

Uniaxial Compressive Strength: Four major bels: 27K to 29 KPSI, two minor beds: 15K to 17 KPSI.

RQD: (Estimated) 90%. Dry Unit Weight: 152 PCF.

Ground Water: Dry

Hardness: Shore 41 to 55 parallel to bedding planes, 41 to 54 perpendicular.

TUNNEL DATA:

Size: 24' wide x 7 1/2' rectangular. Grade: Varies

Ventilation System: 80-100K CFM, pressure

Utility System: 4" air, 4" water, 4" pump, where required.

Water Inflow: Normally none.

Power System: 110V. lighting-all equipment diesel or air powered.

Haulage System: Wagner ST-5 Scooptrams, lo ton shuttle cars to conveyors, l 1/2 CY loaders for cleanup. Personnel and supplies, diesel jeeps and trucks.

Support System: 5/8" x 6' rock bolts on 4' x 4' pattern, 11" wide x 10' roof plates where required.

EXCAVATION DATA:

Conventional Trackless System.

Drilling: Two boom hydrojib jumbos, AR93 drifters, 14' feed.

Drill Round: 35 holes, 1 3/4" diameter, 10 1/2 to 11' deep, and 1-6' buster hole, V-cut.

Explosives: 16# -11/4" x 8", 75% primers, 32#-1 1/4" x 12" RXL, 60% in lifters, 11# coalite 5Y, 1 1/4" x 12" in back holes, 175# AN/FO in remainder of round. Powder factor: 3.5#/CY.

Blasting: Electrical, MS delays.

Mucking: Wagner ST-5 Scooptrams.

Guidance: Transit/Laser.

MDN STUDY SYSTEM DATA SHEET T-C3

Ident. No. 11-3 Sheet 1

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material Size : NA

Spec. Gravity, Material Size : NA

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA %
Plasticity Index NA %

Plastic Limit NA %
Toughness Index NA

Shrinkage Limit NA % Flow Index NA

MATERIAL SIZE

IN.

Angle/Repose 1 In. Drop

@ % Moisture, NA
Angle Slide Steel Plate

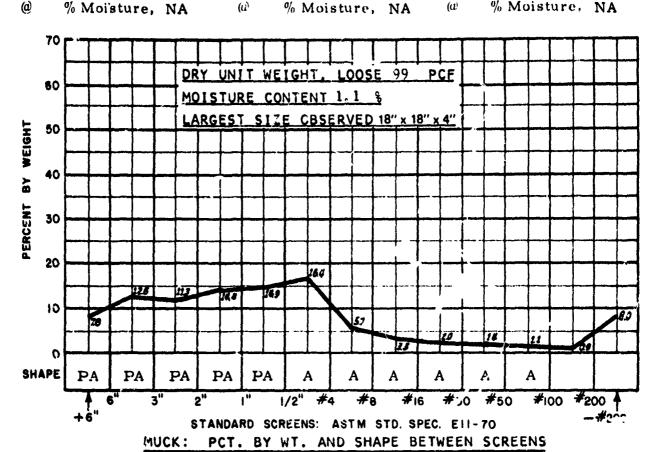
@ % Moisture, NA

Apparent Cohesion PSF (a) % Moisture, NA Bulk Density PCF Angle/Repose 10 In. Drop

w % Moisture, NA

Angle Internal Friction

w % Moisture, NA



SUMMARY

Rock Class: Sedimentary: Shale and siltstone, minor sandstone and limestone, thin to massive, fine to coarse grained. High to medium strength. RQD:(Est.) 90%. DUW: 152 PCF. Ground water: Dry. Hardness: Shore, 41-55.

System Class: Conventional trackless. 24' wide x 7-1/2', rectangular. Two boom jumbo, 35-11' holes, V cut. PF 3.5#/CY. Mucking: Scooptram.

Haulage: Scooptram and/or shuttle cars to conveyor. Support: Nock bolts, 4' x 4' pattern.

MDN STUDY SYSTEM DATA SHEET MDN T-C3 Ident, No. 11-3 Sheet 2

Lithology: Sedimentary, "shale", massive to thinly laminated, interbedded siltstone and shale, with minor sandstone and limestone layers. Grain size varies from fine to coarse, quartz content from 24 to 33%.

Uniaxial Compressive Strength: Four major beds: 27K to 29 KPSI, two minor beds: 15K to 17 KPSI.

RQD: (Estimated) 90%.

Dry Unit Weight: 166 PCF.

Ground Water: Dry.

Hardness: Shore 41.0 to 55 parallel to bedding planes, 41 to 54 perpendicular.

TUNNEL DATA:

Size: 18' wide x 8 1/2' high, rectangular. Grade: Level.

Ventilation System: 20 KCFM exhaust from face, pressure to entry, 46 HP.

Utility System: 2" water line (250 cfm compressor on machine trailer).

Water Inflow: None.

Power System: Cable to trailer mounted transformer.

Haulage: Muck by diesel shuttle car to conveyor, personnel and supplies by diesel truck.

Support System: 5/8" rock bolts, normally 6' long on 4' x 4' spacing, as required.

EXCAVATION DATA:

Machine: Atlas-Copco 4 head prototype. Weight: 180 LT. Two 4' dia. heads are mounted on each side of center on horizontal booms rotated about vertical pivots. Heads are rotated around boom centerlines by motors and reducers integral with the booms; booms and heads rotate from ride to forward positions.

Cutters: 48 Sandvik T. C., drag type, mounted on head peripheries. Leading cutters, 40mm wide, 8 per head; Finish cutters, 120mm wide, 4 per head.

Rotation: Upper heads: 3 1/4 RPM. Lower: 1 5/8 RPM.

Torque: Head rotation: 80 KW. Boom rotation: 100 LT per boom.

Thrust: 488 LT produced by 4 hydraulic cylinders between advanced and front units.

Anchorage: Two top and two side cylinders, approximately 1,000 K#.

Muck Collection: Flight conveyors move muck from sides to a central 26" flight conveyor, discharging on a 9 1/2" dia. star wheel. The wheel ieeus a 25" belt conveyor, transfering muck to a Joy loader and shuttle cars.

Power System: 4160/600/120V, 60 cy. Head rotation: 4-80 KW motors, hydraulics: 2-78 KW motors, 2300 psi.

Guidance: Transit/Laser.

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material

Size

Spec. Gravity, Material

Size

: NA

NA

ATTERBFRG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA % Plasticity Index NA % Plastic Limit NA % Toughness Index NA

Shrinkage Limit NA % Flow Index NA

MATERIAL SIZE

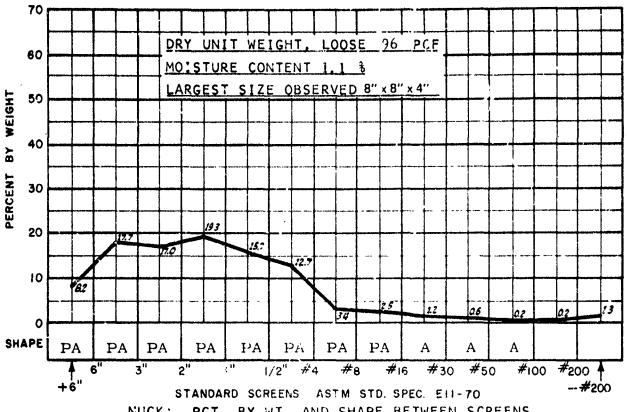
IN.

Angle/Repose 1 In. Drop % Moisture, Angle Slide Steel Plate % Moisture,

Apparent Cohesion PSF % Moisture, NA Bulk Density PCF

% Moistura, NA

Angle/Repose 10 In. Drop % Moisture, NA Angle Internal Friction % Moisture, NA



PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Shale and siltstone, minor sandstone and limestone, thin to massive, fine to coarse grained. High to medium strength. RQD:(Est.) 90%. DUW: 166 PCF. Ground water: Dry. Hardness: Shore 41-55. System Class: TBM, Atlas-Copco. 18' wide x 8-1/2' rect. heading. Sandvik TC "drag" bits, 12/head, 4 heads. RPM 3-1/4 normal. Torque 80KW/head, 100LT/boom. 480LT thrust. Mucking: Flight conveyor - starwheel-relt loader. Haulage: Shuttle car to conveyor. Support: Rock bolts at 4'. MDN STUDY SYSTEM DATA SHEET MDN T-M4 Ident. No. 11-4 Sheet 2

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.

Uniaxial Compressive Strength: 8 KPSI.

RQD: (Estimated) 100 percent. Dry Unit Weight: 176 PCF.

Ground Water: Table above tunnel, occasional seepage from minor fractures

and faults.

Hardness: Shore, 46.

TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent. Ventilation System: 21 K CFM exhaust, 28" pipe.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 40 to 120 gpm. Power System: 4160/480V.

Haulage System: Muck, supplies, personnel, by rail cars.

Support System: None.

EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tungsten Carbide Button, roller, disc, and tricone. Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15" TCB roller.

Rotation: Center cutter-30 RPM, Head-9 RPM.

Torque: Center 150 HP. Head 600 HP.

Thrust: 853 K#

Muck Collection: Buckets from face discharging on 24" belt conveyor.

Power System: Electro-Hydraulic. Total HP: 910.

Guidance System: Laser.

MDN STUDY SYSTEM DATA SHEET T-M3 Ident. No. LAW-2 Sheet 1

Abrasiveness N. A. 1/11/72

Pot. Vol. Change, Material Size = 0.065" : 0

Spec. Gravity, Material Size -0.75": 2.83

ATTERBERG LIMITS, MATERIAL SIZE (-)0.185 IN.

Liquid Limit 12.5 % Plasticity Index 0.2 %

Plastic Limit 12.3 %
Toughness Index 0.05

Shrinkage Limit 9.6 % Flow Index 4.0

MATERIAL SIZE (-)2.0 IN.

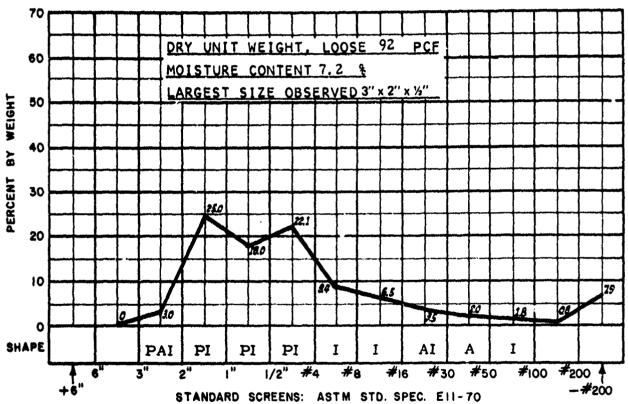
Angle/Repose I In. Drop @ 5.4% Moisture, 39° Angle Slide Steel Plate @ 5.4% Moisture, 31° Apparent Cohesion PSF

Moisture, NA

Bulk Density PCF

Moisture, NA

Angle/Repose 10 In. Drop (# 5,4 % Moisture, 38°) Angle Internal Friction (# 7 % Moisture, 30°)



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules, occasional clay partings. Low strength. RQD: (Est.) 100%. DUW: 176 PCF.

Ground water: Minor. Hardness: Shore 46.

System Class: TBM, Alkirk Hardrock, 13' 8" dia. 28 Lawrence TCBI roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: Center 150 HP, head 600 HP. Thrust: 853 K #. Mucking: Buckets to belt. Haulage: Rail.

Support: None.

MDN STUDY SYSTEM DATA SHEET MDN T-M3 Ident. No. LAW-2 Sheet 2

Lithology: Sedimentary, limestone, light to medium gray, fine grained,

some chert nodules, traces to occasional clay partings.

Uniaxial Compressive Strength: 8 KPSI.

RQD: (Estimated) 100 percent.

Dry Unit Weight: 176 PCF.

Ground Water: Table above tunnel, occasional seepage from minor fractures

and faults.

Hardness: Shore, 46.

TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent. Ventilation System: 20 K CFM exhaust, 28" pipe.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 40 to 120 gpm. Power System: 4160/480V.

Haulage System: Muck, supplies, personnel, by rail cars.

Support System: None.

EXCAVATION DATA:

Machine: A.Kirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg. Company, Tangsten Carbide Button, roller, disc, and ricone. Gage: 5-15" TCb roller. Center: 1-24" TCB tricone. Interior: 11-15" TCB disc., 11-15 TCB roller.

Rotation: Center catter-30 RPM, Head-9 RPM.

Torque: Center 150 HP. Head 600 HP.

Thrust; 855 Kr

Muck Collection: Buckets from face, discharing on 24" belt conveyor.

Power System; Electro-Hydraulic. Total HP: 910.

Guidance System: Laser.

MDN STUDY SYSTEM DATA SHEET T-M3 Ident, No. LAW-3 Sheet 1

Abrasiveness

Pot. Vol. Change, Material

Spec. Gravity, Material

N. A. 1/11/72

Size -0.065" :

0

Size -0.75":

ATTERBFRG LIMITS, MATERIAL SIZE (-)0.185 IN.

Liquid Limit 11.8 % Plasticity Index 1.2 % Plastic Limit 10.6% Toughness Index 0.41 Shrinkage Limit 10.0 %

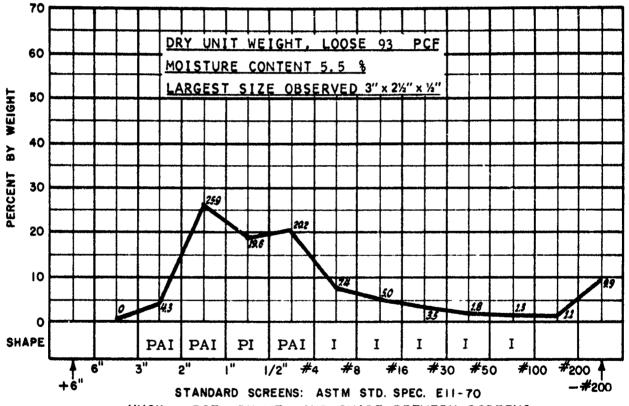
Flow Index 2.9

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @ 6.1% Moisture, 41° Angle Slide Steel Plate @ 8.4% Moisture, 38°

Apparent Cohesion PSF (a) % Moisture, NA Bulk Density PCF % Moisture, NA

Angle/Repose 10 In. Drop ω 6.1% Moisture, 40° Angle Internal Friction @ 7 % Moisture, 320



PCT. BY WT. AND SHAPE BETWEEN SCREENS MUCK:

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chart nodules occasional clay partings. Low strength. RQD: (Est.) 100%. DUW: 176 PCF. Ground water: Minor. Hardness: Shore 46.

System Class: TBM, Alkirk Hardrock. 13' 8" dia. 28 Lawrence TCBI roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: Center 150 HP, head 600 HP. Thrust: 853 K #. Mucking: Buckets to belt. Haulage: Rail.

Support: None.

MDN STUDY SYSTEM DATA SHEET MDN T-M3 Ident. No. LAW-3 Sheet 2

Lithology: Sedimentary, limestone, light to medium gray, fine grained, some chert nodules, traces to occasional clay partings.

Uniaxial Compressive Strength: 10 KPSI.

RQD: (Estimated) 100 percent.

Dry Unit Weight: 176 PCF.

Ground Water: Table above tunnel, occasional seepage from minor

fractures and faults. Hardness: Shore, 46.

TUNNEL DATA:

Size: 13'-8" diameter. Grade (+) 1/4 percent. Ventilation System: 21 K CFM exhaust, 28" pipe.

Utility System: 6" air line, 2" water line, 6" pump line.

Water Inflow: 40 to 120 gpm. Power System: 4160/480V.

Haulage System: Muck, supplies, personnel, by rail cars.

Support System: None.

EXCAVATION DATA:

Machine: Alkirk Hardrock. Weight 400 tons. Cutters: 28-Lawrence Mfg.

Company, Tungsten Carbide Button, roller, disc, and tricone.

Gage: 5-15" TCB roller. Center: 1-24" TCB tricone. Interior: 11-15"

TCB disc., 11-15" TCB roller.

Rotation: Center cutter-30 RPM, Head-9 RPM.

Torque: Center 150 HP. Head 600 HP.

Thrust: 853 K#

Muck Collection: Buckets from face discharging on 24" belt conveyor.

Power System: Electro-Hydraulic. Total HP: 910.

Guidance System: Laser.

1.1

Abrasiveness N. A. 1/11/72

Pot. Vol. Change, Material Size -0.056": 0

Spec. Gravity, Material Size -0.75": 2.73

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 20.2 % Plasticity Index 0.2 %

Plastic Limit 20.0 %
Toughness Index 0.05

Shrinkage Limit 13.5 % Flow Index 4.7

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @ 8.9% Moisture, 42°
Angle Slide Steel Plate @ 8.9% Moisture, 37°

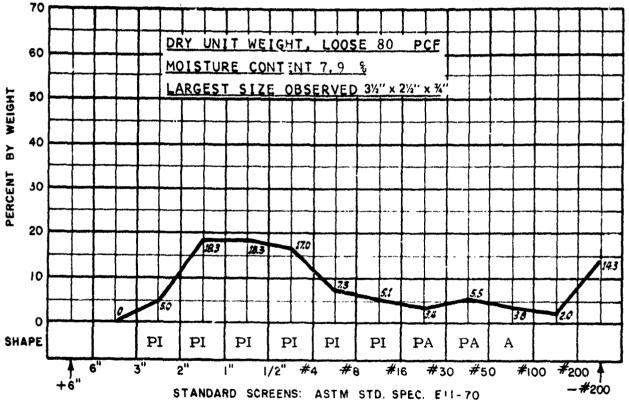
Apparent Cohesion PSF

(a) % Moisture, NA

Bulk Density PCF

(a) % Moisture, NA

Angle/Repose 10 In. Drop @ 8.9% Moisture, 34° Angle Internal Friction @ 8.8% Moisture, 28°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Limestone, fine grained, some chert nodules, occasional clay partings. Medium strength. RQD: (Est.) 100%. DUW: 176 PCF. Ground water; Minor. Hardness: Shore 46.

System Class: TBM, Alkirk hardrock. 13' 8" dia. 28 Lawrence TCBI roller, disc, tricone cutters. RPM: Center 30, head 9. Torque: Center 150 HP, Head 600 HP. Thrust: 853 K #. Mucking: Buckets to belt. Haulage: Rail.

Support: None,

MDN STUDY SYSTEM PATA SHEET AIDN T-M3 Ident. No. LAW-4 Sheet 2

Lithology: Sedimentary, limestone, gray, fine grained, horizontal joint spacing 611 to 11.

Uniaxial Compressive Strength: 36 KPSI.

RQD: (Estimated) 85% Dry Unit Weight: 166 PCF.

Ground Water: Minor, in fault zones.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 11'3" round. Grade: (+).2%.

Ventilation System: 4 KCFM, exhaust, 18" pipe, 25 HP. Utility System: 6" air line, 1" water line, 6" pump line.

Water Inflow: 5-10 gpm. Power System: 4680/440V.

Haulage System: Muck, supplies, personnel, rail cars, 5 ton motors, track

gage 24".

Support System: 4" H rings sets in fault zones, occasional pinned steel

lagging.

EXCAVATION DATA:

Machine: Jarva Mark 11. Total weight: 55 tons.

Citters: 27 Reed steel triple disc and cone. Gage. 4-QK5 steel disc.

Center: 1-QK1 steel cone. Interior: 22-QK3 steel disc.

Rotation: Cutterhead RPM 9.3.

Torque: Maximum 235 Kft#.

Thrust: 618 K# maximum, 596 K.#-operating. Anchor Pressure: 1,650 K#.

Muck Collection: Bucket from face to 18" belt to 24" belt on gantry.

Power System: 440 volt, 4-100 HP motors drive head and 1-40 HP motor for

hyd 'aulic system.

Guidance: Laser.

MDN STUDY SYSTEM DATA SHEET T-M4 Ident. No. MIL-1 Sheet 1

Abrasiveness N. A. #1/11/72

Pot. Vol. Change, Material Size -0.056": 0

Spec. Gravity, Material Size -0.75": 2,89

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

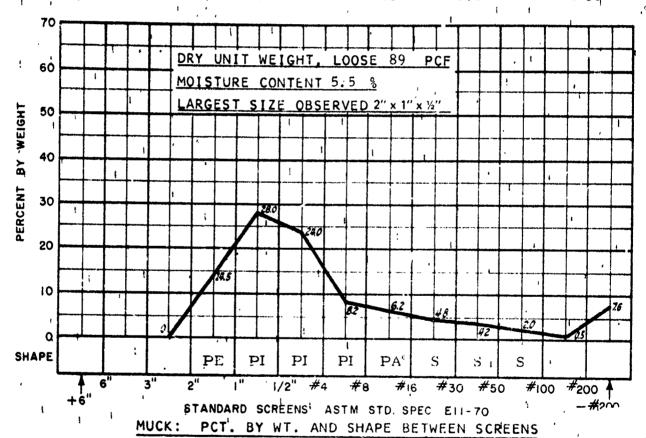
Liquid Limit 16. 90% Plasticity Index 1.121 % Plastic Limit 15.69% Toughness Index: 0.24; Shrinkage Limit 15.46% Flow Index 5.00

MATERIAL SIZE (-)2.0 IN.

Angle/Repose l In. Drop @ 2.5% Moisture, 36° Angle Slide Steel Plate @ 2.5% Moisture, 30°

Apparent Cohesion PSF (# 4.1% Moisture, 95 Bulk Density PCF (# 0.0% Moisture, 86

Angle/Repose 10 In. Drop @ 2.5 % Moisture, 35° : Angle Internal Friction @ 3.5 % Moisture, 35°



SUMMARY

Rock Class: Sedimentary, limestone, fine grained, horizontal joint spacing 6" to 1'. Very high strength. RQD:(Est.) 85%, DUW: 166 PCF.

Ground water: Minor. | Hardness: NA.

System Class: TBM, Jarva Mark 11, 11 2 dia. 27 Reed triple disc cutters. RPM: 9.3. Torque: 235 K ft #. Thrust: 596 K #. Mucking: Bucket to belt. Haulage: Rail. Support: H ring sets in fault zones.

MDN STUDY SYSTEM DATA SHEET MDN T-M4 Ideat. No. MIL-1 Sheet 2

Lithology: Sedimentary, limestone, gray, fine grained, horizontal joint spacing 6" to 1".

Uniaxial Compressive Strength: 36 KPSI.

RQD: (Estimated) 85%

Dry Unit Weight: 166 PCF.

Ground Water: Minor, in fault zones.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 11'3" round, Gra'de: (+) .2%.

Ventilation System: 4KCFM, exhaust, 18" pipe, 25 HP.

Utility System: 6" air line, 1" water line, 6" pump line.

Water Inflow: 5-10 gpm.

Power System: 4680/440V.

Haulage System: Muck, supplies, personnel, rail cars, 5 ton motors, track gage 24".

Support System: 4" H rings sets in fault zones, occasional pinned steel lagging.

EXCAVATION DATA

Machine: Jarva Markill, Total weight: 55 tons.

Cutters: 27 Reed steel triple disc and cone. Gage: 4-QK5 steel disc.

'Center: 1-QK1 steel cone. Interior: 22-QK3 steel disc.

Rotation: Cutterhead RPM 9.3.

Torque: Maximum 235 Kft#.

Thrust: 618 K# maximum, 596 K.#-operating Anchor Pressure: 1,050 K#.

Muck Collection: Bucket from face to 18" belt to 24" belt on gantry.

Power System: 440 volt, 4-100 HP motors drive head and 1-40 HP motor

for hydraulic system.

Guidance: Laser.

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material Size NA

Spec. Gravity, Material Size NA

ATTERBFRG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA % Plasticity Index NA %

Plastic Limit NA % Toughness Index NA Shrinkage Limit NA % Flow IncesNA

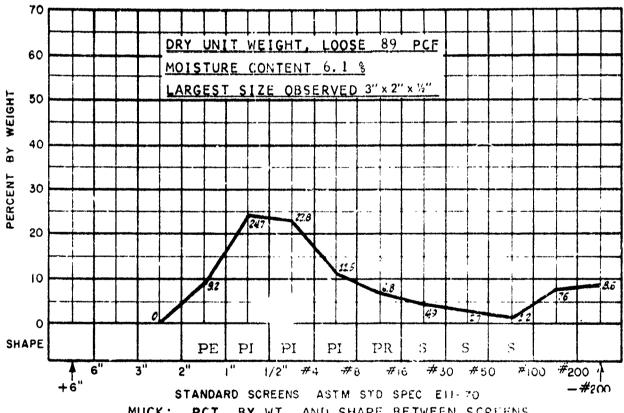
MATERIAL SIZE

IN.

Angle/Repose 1 In. Drop % Moisture, NA Angle Slide Steel Plate % Moisture, NA

Apparent Cohesion PSF (a) % Moisture, NA Bulk Density PCF % Moisture, NA (et

Angle/Repose 10 In. Drop % Moisture, NA Angle Internal Friction " Moisture, NA



PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rick Class: Sedimentary, limestone, fine grained, horizontal coint spacing 6" to 1'. Very high strength. RQD:(Est.) 85%. DUW: 166 PCF.

Ground water: minor. Hardness: NA.

System Class: TBM, Jarva Mark II, 11' 3' dia. 27 Reed triple disc cutters. RPM: 9.3. Torque. 235 K ft #, Thrust: 596 K #. Mucking: Backet to belt. Haulage: Rad. Support: H ring sets in fault Lones.

MDN STUDY SYSTEM DATA SHEET MDN T-M4 Ident. No. MIL-2 Sheet 2

Lithology: Sedimentary, sandstone, medium grained, light brown to red, massive, porous, poorly cemented.

Uniaxial Compressive Strength: 10 KPSI

RQD: (Estimated) 84%
Dry Unit Weight: 150 PCF
Ground Water: Generally dry.

Hardness: NA 1/11/72

TUNNEL DATA:

Size: 12'-11" diameter. Grade: (+) .125%

Ventilation System: 15-17 KCFM exhaust, 36" dia. pipe, 100 HP @ 4100'.

Utility System: 3 1/2" water line, 6" air line, 8" pump line.

Water Inflow: 20-100 gpm.

Power System: 7300/480V

Haulage System: Muck, supplies, personnel, 10 ton locomotives, 10 CY

cars, 24" gage, 65 lb. rail.

Support System: 4^{11} H full rings, 4^{1} centers: 35%; 13^{11} x 9^{1} pans $3/4^{11}$ x 7^{1}

rock bolts: 10%.

EXCAVATION DATA:

Machine: Robbins 141-127, total weight: 125 tons.

Cutters: 30 Robbins steel disc. Gage: 6-11". Center: 1-11" triple disc.

Interior: 23-11.

Rotation: Center cutter integral with head, o or 3 RPM.

Torque: 600 HP

Thrust: 900 K# max., 685 K.# operating. Anchor pressure: 1,000 K #.

Muck Collection: Pickup by buckets fixed to head, discharging on 30" belt

to a 24" x 204' belt on gantry.

Power System: 6-480/240V electric motors drive head. Hydraulic pumps

power thrust and gripper cylinders.

Guidance System: Laser

MDN STUDY SYSTEM DATA SHEET T-M6 Ident, No. LAY-1 Sheet 1

Abrasiveness N. A. 1/11/72

Pot. Vol. Change, Material Size -0.056": 0

Spec. Gravity, Material Size -0.75": 2.66

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 21.20 %
Plasticity Index 3.14 %

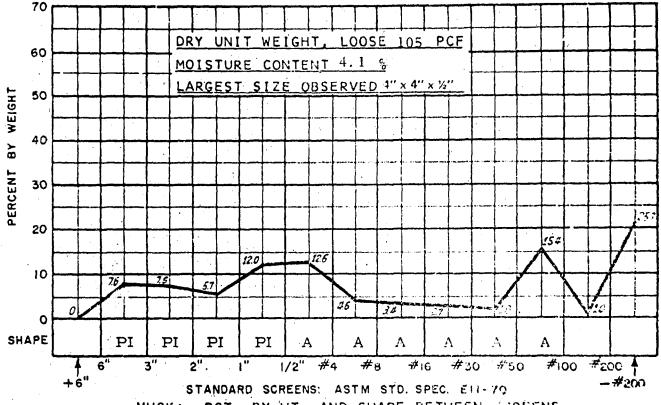
Plastic Limit 17.06 %
Toughness Index 0.52

Shrinkage Limit 15, 17% Flow Index 6, 00

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @3.6% Moisture, 37 Angle Slide Steel Plate @3.6% Moisture, 27 Apparent Cohesion PSF (#3.6 % Moisture, 210 Bulk Density PCF (#0.0 % Moisture, 97.4

Angle/Repose 10 In. Drop @ 3.6 % Moisture, 35° Angle Internal Friction @ 3.6 % Moisture; 38°



MUCK: PCT. BY WT. AND SHAPE BETWEEN JUREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, medium grained, massive, porous, poorly cemented. Medium strength. RQD:(Est.) 84%. DUW: 150 PCF. Ground water: Dry. Hardness: NA.

System Class: TBM, Robbins 141-127, 12'-11" dia. 30 Robbins disc cuttors. 3 or 6 RPM, 600 HP torque, 680 K# thrust. Mucking: Buckets to belt conveyor.

Haulage: Gantry conveyor to rail cars. Support: Steel ring sets, 35%, roof pans and rock bolts, 10% of 4100'.

MDN STUDY SYSTEM DATA SHEET MDN T-M6 Ident, No. LAY-1 Sheet 2

Lithology: Sedimentary, siltstone, fine grained, gray, more than 33% quartz, 30% clay, 10% feldspar, 15% mica, chlorite and gypsum.

Uniaxial Compressive Strength: 2 KPSI

RQD: (Estimated) 70% Dry Unit Weight: 142 PCF

Ground Water: Table above tunnel but sealed off by overlying beds.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 20.5' round, Grade: (+).05%

Ventilation System: 18 KCFM exhaust 30" pipe, 60 HP.

Utility System: 6" air line, 4" pump line

Water Inflow: 50 GPH.

Power System: 4160/440V, rectified to 440 DC for head drive motors.

Haulage System: Muck, supplies, personnel, by 10 CY cars, 15 ton motor,

24" gage 70 lb rail.

Support System: Rock bolts, 8' and $10' \times 3/4''$, set in epoxy with 5' and

13' x 16 gage pans, shotcrete placed to prevent air slacking.

EXCAVATION DATA:

Machine: Dresser TB-205, total weight: 200 tons

Cutters: 36 Dresser steel and TCB insert discs, 32 Kennametal U43 and U44 "pick" bits. Gage: 6-#9T5TD1 TCB insert discs. Center: 6-U43TC bits mounted on a 4" chisel. Interior: 30 Type STD steel discs and 26 U44 TC bits mounted on 4 bit blocks.

Rotation: 0-6 RPM range, 5 RPM normal operating.

Torque: Maximum 879 K ft. #., normal operating 586 K ft. #.

Thrust: Maximum 1,583 K # operating 750 K #.

Anchor Pressure: Maximum 6,-616 K #.

Muck Collection: Buckets from face to 36" belt to 36" belt on 140' gantry.

Power System: Four 180 HP D.C. head motors, one 75 HP for hydraulic

system.

Guidance System: Laser

MDN STUDY SYSTEM DATA SHEET T-M6 Ident. No. NAV-1 Sheet 1

Abrasiveness N.A. 1/11/72 Pot. Vol. Change, Material Size -0.056": 1.3

Spec. Gravity, Material Size -0.75": 3.13

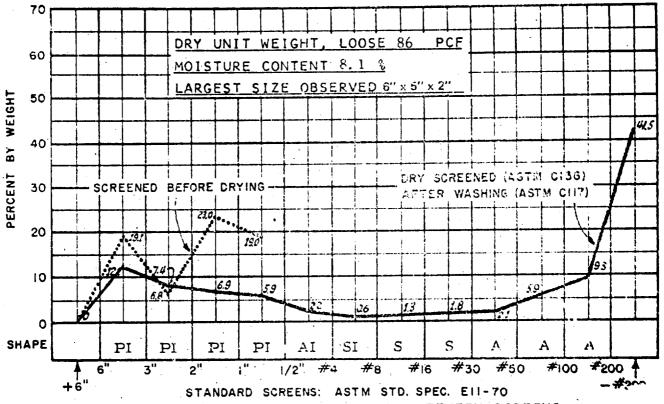
ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 36.80% Plasticity Index 13.19% Plastic Limit 23.61% Toughness Index 1.88 Shrinkage Limit21.04 % Flow Index 7.00

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @7.7% Moisture, 30° Angle Slide Steel Plate @7.7% Moisture, 30° Apparent Cohesion PSF @ 7.5% Moisture, 340
Bulk Density PCF @ 0.0% Moisture, 98

Angle/Repose 10 In. Drop @ 7.7% Moisture, 30° Angle Internal Friction @ 7.5% Moisture, 36°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Siltstone, fine grained. Very low strength.

RQD: (Est.) 70%. DUW: 142 PCF. Ground water: Minor. Hardness: NA.

System Class: TBM, Dresser TB205, 20.5' dia., Dresser disc cutters: 6TCBI and 30 steel, 32 Kennametal, TCBI "pick" bits. RPM: 5, 586 K ft #. torque, 750 K # thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Roof plates and rock bolts, at 3' or 4', continuous.

MDN STUDY SYSTEM DATA SHEET MDN T-M6 Ident, No. NAV-1 Sheet 2

Lithology: Sedimentary, sandstone, gray, medium grained, massive, friable and porous. Grains angular to subrounded, primarily quartz, poorly cemented.

Uniaxial Compressive Strength: Less than 1 KPSI, disintegrates when wet.

RQD: (Estimated) 60% Dry Unit Weight: 117 PCF

Ground Water: Table above tunnel but sealed off by overlying beds.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 20.5' diameter. Grade: (+).05%

Ventilation System: 18 KCFM exhaust, 30" pipe, 60 HP.

Utility System: 6" air line, 4" pump line

Water Inflow: 50 GPH.

Power System: 4160/440V, rectified to 440 DC for head drive motors.

Haulage System: Muck, supplies, personnel, by 16 CY cars, 15 ton motor,

24" gage 70 lb rail.

Support System: Rock bolts, 8' and $10' \times 3/4''$, set in epoxy, with 5' and

13' x 16 gage pans, shotcrete placed to prevent air slacking.

EXCAVATION DATA:

Machine: Dresser TB-205, total weight: 200 tons

Cutters: 36 Dresser steel and TCB insert discs, 32 Kennametal U43 and U44 "pick" bits. Gage: 6-#9T5TD1 TCB insert discs. Center: 6-U43TC bits mounted on a 4" chisel. Interior: 30 Type STD steel discs and 26 U44TC bits mounted on 4 bit blocks.

Rotation: 0-6 RPM range, 5 RPM normal operating.

Torque: Maximum 879 K ft. #., normal operating 586 K ft. #.

Thrust: Maximum 1,583 K #. operating 750 K #.

Anchor Pressure: Maximum 6,616 K #.

Muck Collection: Buckets from face to 36" belt to 36" belt on 140" gantry.

Power System: Four 180 HP D.C. head motors, one 75 HP for hydraulic system.

Guidance System: Laser

MDN STUDY SYSTEM DATA SHEET T-M7 Ident. No. NAV-2 Sheet 1

MÚCK DATA

Abrasiveness

Pot. Vol. Change, Material NA

Size

Spec., Gravity, Material

N. A. 1/11/72

Size

ιJΑ

ATTERBERG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA % Plasticity Index NA % Plastic Limit NA % Toughness Index NA Shrinkage Limit NA %

Flow Index NA

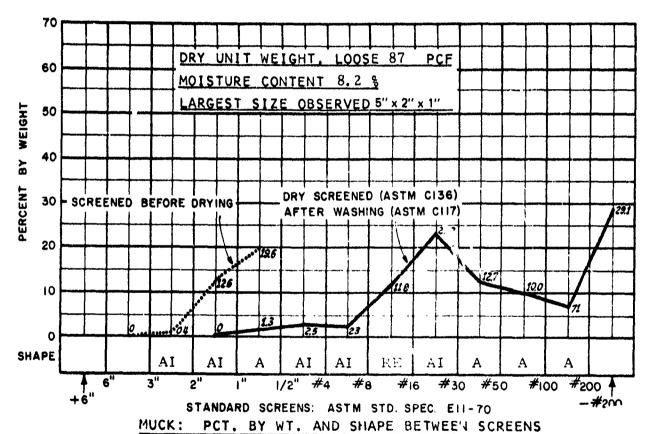
MATERIAL SIZE

IN.

Angle/Repose 1 In. Drop % Moisture, NA Angle Slide Steel Plate % Moisture, NA

Apparent Cohesion PSF (u) % Moisture, NA Bulk Density PCF % Moisture, NA

Angle/Repose 10 In. Drop % Moisture, (w Angle Internal Friction % Moisture, NA



SUMMARY

Rock Class: Sedimentary: Sandstone, massive, friable, porous, med um grained. Very low strength. RQD (Est.) 60%. DUW: 117 PCF. Ground water: Minor. Hardness: NA.

System Class: TBM, Dresser TB205, 20.5' dia. Dresser, disc cutters 6TCBI and 30 steel, 32 Kennametal, TCBI "pick" bits. RPM; 5, 586 K ft # torque, 750 K # thrust. Mucking: Buckets to belt. Haulage: Rail. Support: Roof plates

and rock bolts, at 3' or 4', continuous.

MDN STUDY SYSTEM DATA SHEET MDN T-M7 Ident. No. NAV-2

Lithology: Sedimentary, sandstone, coarse grained, poorly consolidated,

arkosic, with minor layers of thin seamed siltstone.

Uniaxial Compressive Strength: 50 to 150 PSI dry-disintegrates when wet.

RQD: (Estimated) 30%.
Dry Unit Weight: 125 PCF.

Ground Water: Saturated when first opened.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 10' high by 8' wide, rectangular. Grade (+) 1/2%.

Ventilation System: 5 to 7 KCFM, pressure, 18" dia. vent tube.

Utility System: 4" airline. Water Inflow: 20-25 gpm.

Power System: 440/110V, trailing cable.

Haulage System: Muck, personnel and supplies by rail cars, 24" gage,

40# rail.

Support System: None, rock bolts and/or shotcrete in bad ground.

EXCAVATION DATA:

Machine: Alpine Miner, Type F6-A. Total Weight: 11 tons.

Cutters: 72, Kennametal U43K, Carbide tipped, "pick" type. Cutters, mounted on twin ripper heads, rotating about a horizontal axis at 90° to a boom which moves the heads vertically and horizontally.

Rotation: 60 RPM, motor and gear box integral with boom.

Torque: 50.4 HF

Thrust: Sumping thrust from crawler motors, 2 @ 20.4 HP. Vertical and horizontal by hydraulic cylinders powered by a 10.4 HP electro-hydraulic system.

Anchor Pressure: Crawlers only.

Muck Collection: Central 14" chain conveyor, fed by gathering arms, discharges on an 18" x 30" belt feeding 116" of 20" Serpentix conveyor. Transverse folds are molded into 20" x 8" long rubber Serpentix sections, which are bolt connected at reinforced flanges connected to an endless chain driven by a sprocket. Folds allow inside edge to compress and outside to expand on curves. Vertebral side rail sections, alternating with straight sections, are supported by wheeled gantry legs riding a 00" gage track, under which cars are spotted.

Power System: 440V, trailing cable. Guidance System: Transit/Laser.

MDN STUDY SYSTEM DATA SHEET T-M7 Ident. No. WNG-1 Sheet 1

Abrasiveness N. A. 1/11/72

Pot. Vol. Change, Material Size -0.056"

Spec. Gravity, Material

Size -0.75":

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 24. 90 % Plasticity Index 4.93 % Plastic Limit 19.97 % Toughness Index 0.66

Shrinkage Limit 19, 94 %

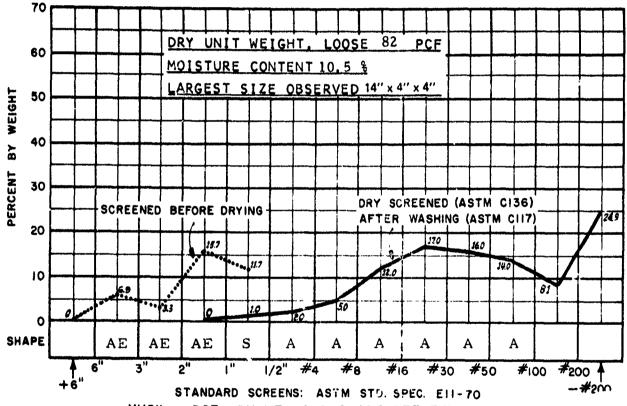
Flow Index 7.40

MATERIAL SIZE (-)2.0 IN.

Angle/Repose 1 In. Drop @10.1% Moisture, 34³ Angle Slide Steel Plate @10.0% Moisture, 320

Apparent Cohesion PSF (a) 10.6% Moisture, 0 Bulk Density PCF (a) 0.0 % Moisture, 85

Angle/Repose 10 In. Drop (w10.1% Moisture, 31° Angle Internal Friction (a)10.6% Moisture, 27°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Sandstone, coarse grained, poorly consolidated, arkosic, minor thin seamed siltstone. Very low strength. RQD: (Est.) 30%.

DUW: 125 PCF. Ground water: Saturated. Hardness: N.A.

System Class: TBM, Alpine F6A, twin head, 10' high x 8' heading. 72 Kennametal TCBI pick type bits. 60 RPM, 50.4 HP head torque, 10.4 HP boom power, 40.8 HP sumping thrust. Mucking: Gathering arms-flight conveyor. Haulage: Elevating conveyor - Serpentix conveyor on gantry - rail cars. Support: Normally none. MDN STUDY SYSTEM DATA SHEET MDN T-M7 Ident. No. WNG-1 Sheet 2

Lithology: Sedimentary, sandstone, coarse grained, poorly consolidated, arkosic, with minor layers of thin seamed siltstone, varying concentrations of replacement silica.

Uniaxial Compressive Strength: 50 to 150 PSI dry-disintegrates when wet.

RQD: (Estimated) 30% Dry Unit Weight: 125 PCF

Ground Water: Saturated when first opened.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 5' wide x 9' high, nominally rectangular. Grade: Varies. Ventilation System: 5 to 7 KCFM, pressure, 18" vent tube.

Utility System: 2" air, 1" waterline.

Water Inflow: 20-25 gpm when levels are first opened; generally dry after drainage.

Power System: None in development headings, 440V to scraper hoists, 110V lighting.

Haulage System: Muck is scraped from the face of a cross cut to a slusher drift, cross scraped to a muck raise, and loaded into 4 cu. ft. rocker dump rail cars on main level about 80' below. Scrapers are 42", hoists 15 HP. Personnel access by ladder, supplies by rail cars and air-powered hoists through raises.

Support System: None. Rockbolts in bad ground.

EXCAVATION DATA:

Conventional Scraper-Rail Haulage System.

Drilling: LeRoi Model 35 jackhammers mounted on 6' airfe. . legs.

Drill Round: Five hole box or vertical line burn cut, 6' depth, included in 18 hole round, all holes 1 1/2" diameter.

Explosives: 50# Dupont 40% Gelex #2, Powder factor: 5#/cu. yd.

Blasting: Safety fuse and caps.

Mucking System: 42" Scrapers, 15 HP hoists.

MDN STUDY SYSTEM DATA SHEET T-C7 Ident. No. WNG-2 Sheet 1

Abrasiveness N. A. 1/11/72

Pot. Vol. Change, Material Size -0.056"

Spec. Gravity, Material

Size -0.075": 2.72

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

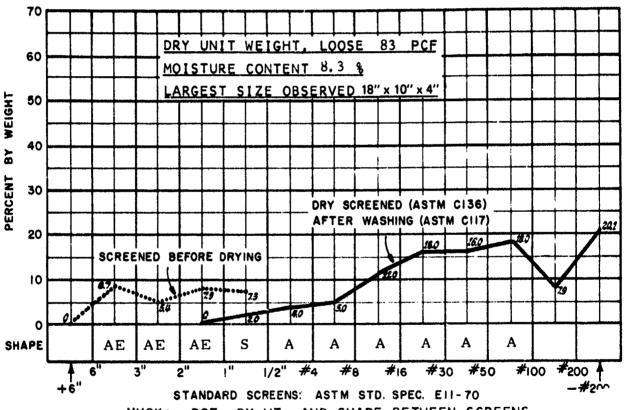
Liquid Limit25.25 % Plasticity Index 0.51 % Plastic Limit 24.74 % Toughness Index 0.13 Shrinkage Limit23.37 % Flow Index 4.00

MATERIAL SIZE (-)2.0 IN.

Angle/Repose I In. Drop @ 9.0% Moisture, Angle Slide Steel Plate @ 9.0 % Moisture,

Apparent Cohesion PSF (a) 9 % Moisture, 0 Bulk Density PCF (a) 0. 0 % Moisture, 86

Angle/Repose 10 In. Drop (w 9,0% Moisture, 31° Angle Internal Friction (a) 9 % Moisture, 280



PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sadimentary: Sandstone, coarse grained, poorly consolidated, arkosic, minor thin seamed siltstone, varying replacement silica. Very low strength. RQD: (Est.) 30%. DUW: 125 PCF. Ground water: Saturated. Hardness: NA. System Class: Conventional Scraper-Rail. 5' wide x 9' high, rectangular. Airleg jackhammer, 18-6' holes, burn cut. PF 5#/CY. Mucking: Scraper to raise. Haulage: rail cars - skip to surface. Support: Normally none.

MDN STUDY SYSTEM DATA SHEET MDN T-C7 Ident. No. WNG-2

Lithology: Sedimentary, sandstone, arkosic, irregularly

bedded, loosely consolidated with layers and lenses of silty mudstone.

Uniaxial Compressive Strength: Less than one KPSI.

RQD: (Estimated) 0 to 35%. Dry Unit Weight: 113 PCF

Ground Water: Saturated; water table above tunnel, heading is drained in

advanced by lateral pilot holes in ribs.

Hardness: NA 1/11/72

TUNNEL DATA:

Size: 21 ft., diameter. Grade: (+) 0.2%.

Ventilation System: 20 KCFM, 36" pipe, pressure at face, exhaust in

access.

Utility System: 6" air line, 6" pump line.

Water Inflow: 200 gpm. Power System: 4160/480V.

Haulage System: Muck, personnel, supplies by rail cars.

Support System: Continuous, precast concrete rings 8" and 10" thick,

erected in four-4' segments.

EXCAVATION JATA:

Shield: Robbins 221S ripper, Total weight: 285 tons

Thrust: 3,500 tons total.

Muck Collection System: Muck is ripped from the face by a ripper tooth and drawn through the shield to a 6' conveyor by hydraulic ram with a bucket opposite the ripper tooth.

Power System: Hydraulic. Guidance System: Laser

Abrasiveness

Pot. Vol. Change, Material

Spec. Gravity, Material,

N. A. 1/11/72

Size-0.065"

Size -0.185!!:

ATTERBERG LIMITS, MATERIAL SIZE (-)0.185 IN.

Liquid Limit 17.75% Plasticity Index 1.56 % Plastic Limit 16.19% Toughness Index

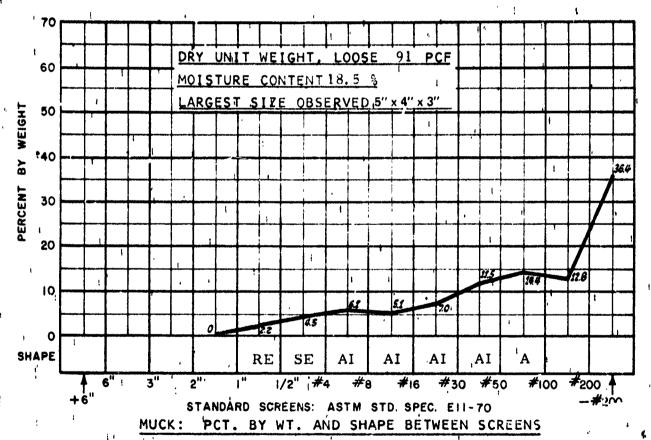
Shrinkage Limit 13, 94 % 1 Flow Index 5.8

MATERIAL SIZE(-)0. 185IN

Angle/Repose 1 In. Drop @14.3% Moisture, 38° Angle Slide Steel Plate @12.5% Moisture, 36°

Apparent Cohesion PSF (1) % Moisture, NA · Bulk Density PCF '% Moisture, NA

Angle/Repose 10 In. Drop (w14.13% Moisture, 330) Angle Internal Friction (a) 13 % Moisture, 420



Rock Class: Sedimentary, sandstone, arkosic, loosely consolicated, with layers and lenses of silty, mudstone. Very low strength. RQD:(Est.) 0-35%.

DUW: 113 PCF. Ground water: saturated. Hardness: NA.

System Class: Shield, Robbins 221S ripper, 21' dia. Thrust 3,500 tons.'

Mucking: Hydraulic boom openated bucket scraper to conveyor. Haulage: Rail.

Support: Continuous, precast concrete ring segments.

MDN STUDY SYSTEM DATA SHEET 1 Ident. No. SF-1 Sheet 2

Lithology: Sedimentary, sandstone, biotite rich siltstone, poorly to well consolidated, poorly to well sorted.

Uniaxial Compressive Strength: 2 KPSI

RQD: (Estimated) 50%

Dry Unit Weight: 142 PCF

Ground Water: Sandstone saturated, water table above tunner, heading

drained in advanced by lateral pilot hole's in ribs.

Hardness: NA 1/11/72

TUNNEL DATA:

Size: 21 ft., round, Grade: (+) 0.2 pct.

Vientilation System: 20 KCFM, 36" pipe, pressure at face, exhaust in

access.

Utility System: 6" air line, 6" pump line.

Water Inflow: 20 gpm

Power System: 4160/480V

Haulage System: Muck, personnel, supplies by rail cars.

Support System: Continuous, precast concrete rings 8" and 10" thick,

erected in four 4' segments.

EXCAVATION DATA:

Shield: Robbins, 221S ripper, total weight: .285 tons,

Thrust: 3,500 tons total.

'Muck Collection System: Muck is ripped from face by a ripper tooth and drawn through the shield to a 6' conveyor by hydraulic ram; with a bucket opposite the ripper tooth.

Power System: Hydraulic Guidance System: Laser

MDN STUDY SYSTEM DATA SHEET T-S5' Ident. No. SF-2 Sheet 1

Abrasiveness N. A. 1/11/72

Pot. Vol. Change, Material Size -0.056": 0

Spec. Gravity, Material Size -0,75": 3,02

ATTERBERG LIMITS, MATERIAL SIZE (-)0.056 IN.

Liquid Limit 31.5 %
Plasticity Index 4.7 %

Plastic Limit 26.8 % 5 Toughness Index 0.61 Shrinkage Limit 21.5% Flow Index 7.6

MATERIAL SIZE (-)1.0 IN.

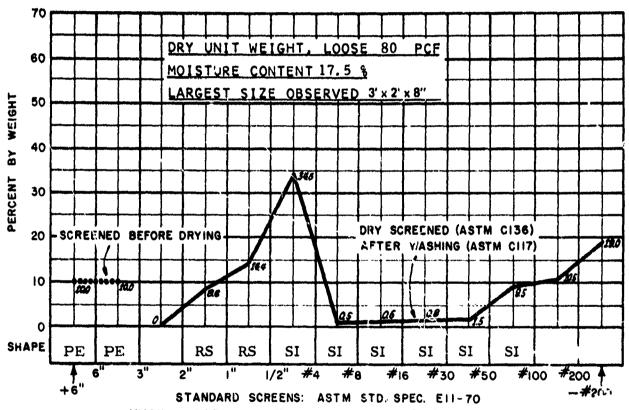
Angle/Repose l In. Drop @15.1% Moisture, 38° Angle Slide Steel Plate @15.1% Moisture, 30° Apparent Cohesion PSF

(a) % Moisture, NA

Bulk Density PCF

(a) % Moisture, NA

Angle/Repose 10 In. Drop @15.1% Moisture, 36° Angle Internal Friction @ 15% Moisture, 27°



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary, sandstone and siltstone, poorly to well consolidated. Very low strength. RQD: (Est.) 50%. DUW: 142 PCF. Ground water: saturated. Hardness: NA.

System Class: Shield, Robbins 221S ripper, 21' dia. Thrust 3,500 tons.

Mucking: Hydraulic boom operated bucket scraper to conveyor. Haulage: Rail.

Support: Continuous, precast concrete ring segments.

MDN STUDY SYSTEM DATA SHEET MDN T-S5

Ident. No. SF2

Sheet 2

Lithology: Sedimentary, mudstone, dark gray, fine grained, massive.

Uniaxial Compressive Strength: 11 KPSI dry.

RQD: (Estimated) 90%.

Dry Unit Weight: 144 PCF.

Ground Water: Generally dry.

Hardness: NA 1-11-72

TUNNEL DATA:

Size: 10' high x 9' wide (7'-6" top, 9'-6" bottom). Grade: (+) 1/2%. Ventilation System: 5 KCFM, exhaust from face, pressure to venthole, 16" flexhaust, 24" vent tube, 2-25 HP Axivane fans.

Power System: Muck, personnel and supplies by rail cars, 36" gage, 45#

rail.
Support: 4" WF steel sets at 3' or 6'.

EXCAVATION DATA:

Machine: Alpine Miner, Type F6-A. Total Weight: 11 tons.

Cutters. 40 Kennametal U43KF, Carbide tipped, "pick" type. Cutters mounted on twin ripper heads, rotating about a horizontal axis at 900 to a boom which moves heads vertically and horizontally.

Rotation: 78 RPM, motor and gear box integral with boom.

Torque: 50.4 HP.

Thrust: Sumping thrust from crawler motors, 2 @ 20.4 HP, vertical and horizontal by hydraulic cylinders powered by a 10.4 HP electro-hydraulic system.

Anchor Pressure: Crawlers only.

Muck Collection: Central 14" flight conveyor fed by two gathering arms mounted on an inclined apron, discharges on an 18" elevating conveyor loading rail cars.

Power System: 440V, trailing cable. Guidance System: Transit/Laser.

MDN STUDY SYSTEM DATA SHEET T-M6 Ident. No. KM-1 Sheet 1

Abrasiveness N. A. 1/11/72 Pot. Vol. Change, Material Size

NA

Spec. Gravity, Material

Size NA

ATTERBFPG LIMITS, MATERIAL SIZE

IN.

Liquid Limit NA % Plasticity Index NA % Plastic Limit NA % Toughness Index NA Shrinkage Limit NA % Flow Index NA

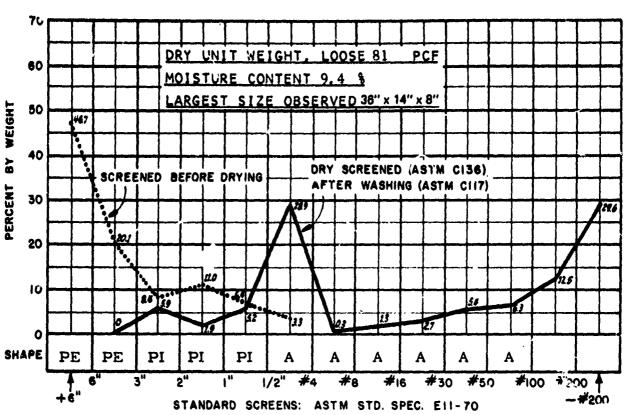
MATERIAL SIZE

IN.

Angle/Repose 1 In. Drop % Moisture, NA Angle Slide Steel Plate % Moisture, NA

Apparent Cohesion PSF % Moisture, NA Bulk Density PCF (a) % Moisture, NA

Angle/Repose 10 In. Drop % Moisture, Angle Internal Friction % Moisture, NA



MUCK: PCT. BY WT. AND SHAPE BETWEEN SCREENS

SUMMARY

Rock Class: Sedimentary: Mudstone ("shale") fine grained, massive. Medium strength. RQD: (Est.) 90%. DUW: 144 PCF. Ground water; Dry. Hardness: NA.

System Class: TBM, Alpine F6A, twin head, 10' high x 9' heading. 40 Kennametal TCBI pick type bits. 78 RPM, 50.4 HP head torque, 10.4 HP boom power, 40.8 HP sumping thrust. Mucking: Gathering arms - flight conveyor. Haulage: Elevating conveyor-rail cars. Support: Steel sets at 3' or 6', continuous. MDN STUDY SYSTEM DATA SHEET MDN T-M6 Ident. No. KM-1 Sheet 2